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DURATIONAL CONTROL OF DEFENSIVE BURYING IN RATS:
AN INVESTIGATION OF A SPECIES-SPECIFIC
DEFENSE REACTION

by

Stephen Gregory Goldberg

A dissertation submitted in partial fulfillment
of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

in

Psychology

UTAH STATE UNIVERSITY
Logan, Utah

1988

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Finally, in completing this, I would like to quote a fictional character, Captain James T. Kirk, of the Starship, U.S.S. Enterprise, who said, "Beam me up, Scotty." Mission accomplished.

Stephen Gregory Goldberg

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ABSTRACT

Durational Control of Defensive Burying in Rats:
An Investigation of a Species-Specific
Defense Reaction

by

Stephen G. Goldberg, Doctor of Philosophy
Utah State University, 1988

Major Professor: Dr. J. Grayson Osborne

Department: Psychology

Six experiments were run to determine whether the duration of conditioned defensive burying (CDB) in rats is a function of its consequences.

Four experiments developed the methodology. Experiment 1 replicated the standard one-trial experiment, where rats are shocked once by a prod. All three rats exhibited CDB. Experiment 2 used a lever-press-for-water contingency to force recontact with the lever, following shock deliveries in Sessions 6 and 14. All three rats buried the lever in both sessions. Experiment 3 replicated Experiment 2, employing albino and hooded rats. All six buried the lever. The albinos exhibited longer burying durations. Experiment 4 used the lever-press-for-water contingency but employed extinction to test whether rats would bury the lever under that condition. They did not.

Experiment 5 used three groups of rats to determine

whether burying durations are a function of CDB's consequences. Groups LS and LSH had enough sawdust to cover the lever, but a hole under the lever was opened during LSH's burying. Group SS lacked enough sawdust to cover the lever. The groups' mean burying durations (MBDs) were not significantly different in Session 6. Following Session 14, group differences and a group-by-session interaction were statistically significant. Effect sizes for Groups LS and SS were large. Group LS's MBD increased, Group LSH's remained unchanged, and Group SS's decreased.

Experiment 6 used two groups of rats to determine whether MBDs are a function of shock source visibility. Group C's substratum consisted of uncolored, transparent Plexiglas blocks. Group B had black, opaque blocks. Only the group-by-session interaction was statistically significant. The MBDs of Groups B and C paralleled those of Groups LS and SS in Experiment 5. The effect sizes for C and B were large and medium, respectively.

CDB occurred in all experiments where the rats received shocks, and CDB was reproduced in experiments where the animals were forced to recontact the shock source through a lever-press-for-water contingency.

CDB durations are a function of their consequences. Rats whose burying covers or blocks the shock source from view exhibit longer burying durations in succeeding shock trials. Rats whose burying is ineffective exhibit shorter durations.

(134 pages)

CHAPTER I

STATEMENT OF THE PROBLEM

Defensive burying, a behavior by which many species of rodent avoid sources of aversive stimulation by covering such sources with the available substratum, was first described in detail by Pinel and Treit (1978). When rats are given a single shock through a stationary prod in the presence of some movable substratum, they do not attack or flee from the prod, nor do they freeze in its presence; they bury it. This response, which potentially enables the rats to avoid future contact with the prod, is called defensive burying (Pinel & Treit, 1978, 1979).

In the experimentation on defensive burying that has occurred since Pinel and Treit named the response, the typical procedure has been to preexpose the rodents to the test environment, apply an aversive stimulus, and measure the amount of time that the rodents use the substratum to bury the source of the aversive stimulus.

This procedure has been very effective to determine the conditions and parameters under which defensive burying is elicited, as well as the species that engage in defensive burying. Additionally, two types of defensive burying have been identified: conditioned and unconditioned. Unconditioned burying is similar to neophobia (the fear of novel stimuli), and novel stimuli are buried as if they were aversive. Conditioned defensive burying is based on the actual pairing of neutral and aversive stimuli.

Despite these gains in knowledge, however, very

little is known about conditioned defensive burying as a complete response sequence, that is, from beginning to end. Even though the conditions necessary for its elicitation have been established, no research to date has attempted to determine the conditions under which any single instance of the response is terminated.

The possible reasons for the termination of conditioned defensive burying can be divided into two categories: organismic and functional. In the first case, it may be simply that just as the animal does not have to learn to bury, it does not have to "learn" to stop: it simply does so because, as a part of the animal's genetic makeup, the response terminates "on its own," so to speak, in the same manner that simple reflexes terminate without regard to environmental changes resulting from them.

The other possibility (and the two are not necessarily mutually exclusive) is that response-environment interactions control the response. If such is the case, it would appear, from the work of Jackson and Allgeyer (1985), that the critical variable is stimulus salience--in this case, stimulus visibility. If termination of conditioned defensive burying is a function of stimulus visibility, termination should occur shortly after the source of the conditioned aversive stimulus (e.g., the shock prod) is blocked from view.

The experiments described herein will evaluate each of these two possibilities: 1) that conditioned defensive burying terminates without regard to its effects on the environment; 2) that conditioned defensive burying terminates as a function of its alteration of the environment.

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

Conditioned defensive burying (CDB) is a behavior which, in and of itself, is of little importance. Its importance lies in the fact that it is the most recently described behavior that does not "fit" traditional two-process learning theories. As a result, it is studied not only to discover more about it, but also because the potential is present for an increased understanding of learning in general.

In this context, this review of the CDB literature will begin with a brief coverage of two-process theories. It will then discuss the burying response, its elicitors, and other areas into which the investigation of CDB has progressed.

The Bases of Two-Process Learning Theories

Historically, psychologists approached the study of learning with the basic, underlying assumption that the elements in any learning situation were arbitrary and interchangeable (e.g., Roper, 1983; Seligman & Hager, 1972; Shettleworth, 1972). That is, stimuli, responses, or experimental settings could be varied without affecting the results of the experiments in which they were

employed. As such, conditioning was studied as an isolated process (Sevenster, 1973), one in which these variables were assumed to have no effects on the generalizability of the "laws" being investigated.

Additionally, most textbooks that dealt with the subject of learning typically were organized along the lines of a "two-factor" or "two-process" approach that divided learning into two categories: operant (or instrumental) and respondent (or classical). This explicit distinction was first made in Poland by Miller and Konorski (1928, cited in Hearst, 1976). In respondent conditioning, the delivery of the reinforcer is dependent on a prior stimulus and in operant conditioning, on a prior response.

This distinction was expanded by Skinner, who said that respondent conditioning dealt primarily with those behaviors typically characterized as reflexes, the majority of which involved the glands and smooth, internal muscles, and that operant conditioning dealt primarily with behaviors that operate upon the organism's environment, the majority of which involved the striated skeletal muscles (Skinner, 1935).

The first paper that provided a more precise means of distinguishing the two types of behavior was one by Schlosberg (1937), who made the distinction on the basis of the operations carried out by the experimenter. In respondent conditioning, the experimenter paired the reinforcer with a stimulus, and in operant conditioning, the experimenter paired the reinforcer with a response. Schlosberg also developed hypotheses that described the different learning processes and the different mechanisms of reinforcement involved with each procedure. His paper laid the foundation for most of the more recent work in two-process theories (e.g., Rescorla & Solomon, 1967).

Two-process learning theories stayed in the forefront

of experimental psychology for many years and probably reached their zenith at about the time that Rescorla and Solomon (1967) published their paper dealing with the subject. In it, Rescorla and Solomon stated that the laws of classical conditioning were probably "the laws of emotional conditioning or laws of acquired drive states" that "can serve either as motivators or reinforcers of instrumental responses" (Rescorla & Solomon, 1967, p.172). There were difficulties, however, because many responses sometimes appeared to be operants and at other times, appeared to be respondents. As a result, Rescorla & Solomon were forced to conclude that there was insufficient evidence to support the idea that the two conditioning procedures justified "the claim that two independent processes are acting" (1967, p. 163).

Two-Process Theories in Decline

Less than a year after the Rescorla and Solomon paper was published, Brown and Jenkins (1968) published the first paper on autoshaping, a process in which a lighted key is paired with the presentation of food that results in pigeons pecking the key. This pecking occurs even when the peck, itself, results in the omission of the food (Williams & Williams, 1969). This respondent conditioning of directed movements "would presumably make it now even more difficult for Rescorla and Solomon to distinguish between Pavlovian and instrumental responses" (Hearst, 1976, p. 213).

In actuality, respondent conditioning of directed skeletal movements was discovered as early as 1937. Zener (1937, cited in Millenson & Leslie, 1979) found that after traditional Pavlovian procedures were employed to condition the salivation reflex of dogs to a bell, the release of the dogs resulted in their approach to the bell. Even Pavlov, himself, reported similar findingsn

He described how the formation of a conditioned reflex "is quickly replaced by the special motor reflex peculiar to the given unconditioned stimulus" (Pavlov, 1941, p. 120) and stated that when conditioned stimuli are initially established, "the first reaction elicited by the conditioned stimulus usually consists in a movement towards the stimulus." He added that, "if the stimulus is within reach, the animal even tries to touch it, with its mouth" (Pavlov, 1941, p. 150).

It was clear that in cases of the conditioning of the alimentary reflex, "the animal may lick the electric lamp, or appear to take air into its mouth, or to eat the sound" (Pavlov, 1941, p. 120). Describing this phenomenon even further, Pavlov wrote that when dogs of his engaged in these behaviors, the animal was "licking his lips and making the noise of chewing with his teeth as though it were a matter of having the food itself" (1941, p. 120). A phenomenon apparently analogous to this was described by Moore (1973), who demonstrated that the key-peck response of pigeons differs topographically depending on the reinforcer employed, that is, one topography for water reinforcers and another for food reinforcers.

More recent work demonstrated that rats also use different lever press topographies for food than they do for water (Hull, Bartlett, & Hill, 1981). These and numerous other experiments led to the realization that there is probably a respondent component involved in the results obtained in all operant experiments, that is, respondent conditioning is probably a part of all operant conditioning (Rescorla, 1988). Parceling out the respondent contributions to these results is a virtually impossible task (Rescorla & Holland, 1976).

Nonsupport of the Principles of Operant Conditioning

Besides the difficulties in distinguishing operant from respondent conditioning, data have been accumulating for years that demonstrate that all of the "laws" of operant conditioning cannot be supported. These are the so-called "anomalies" that have appeared in the literature. Two of the primary principles of operant conditioning are that reinforcers are transsituational and that, for reinforcers to be effective, their delivery must be immediate.

Reinforcer transsituationality (also referred to as equipotentiality) means that, under equivalent motivational conditions, a reinforcer will be equally effective in controlling any behavior (e.g., Schnaitter, 1978; Skinner, 1953). In its simplest form, for example, if a rat is deprived of food, food should function as a reinforcer for any response chosen by the experimenter.

In fact, the man who defined the Law of Effect, Edward Thorndike, was the first experimenter to report that transsituationality was not supported by his results. Regardless of the reinforcer he employed, Thorndike was unable to strengthen, or increase the rate of, grooming behaviors in a number of species (Thorndike, 1911, cited in Shettleworth, 1972, 1973).

In 1961, Breland and Breland published an article in which they described the ways in which many different types of animals consistently failed to learn the behaviors they were "supposed to" learn. Additionally, there were many cases in which behaviors that had been learned initially later drifted back toward instinctive, that is, apparently unlearned, species-specific patterns of behavior, even when these behaviors delayed or prevented the delivery of reinforcers. More surprisingly, increasing the animals' deprivation often intensified the

anomalous result (Breland & Breland, 1961). A plethora of experiments demonstrating that transsituationality is experimentally invalid has since appeared (e.g., Bolles & Riley, 1983; Charlton, 1983; Sevenster, 1973; Shettleworth, 1973; Walters & Glazer, 1971).

The second "law" of operant conditioning, that which concerns immediacy of reinforcement (e.g., Michael, 1985; Skinner, 1953), has also been undermined by recently obtained data. A number of experiments employing apparatus not typical to the usual operant experiment, such as "T" mazes and runways, have demonstrated this repeatedly (for a discussion, see Garcia & Levine, 1976). It now appears that immediacy of reinforcement is important only in situations in which a continuous stream of behavior occurs, in order to "flag" the reinforced response. Immediacy, *per se*, is not a necessary condition for effective reinforcement. In fact, "the psychological effect of time depends upon where and how the time is spent" (Garcia & Levine, 1976, p. 195).

Nonsupport of Respondent Conditioning

Insofar as respondent conditioning is concerned, only one experimental "crisis" has occurred in the literature and this, to date, has been accommodated. The area of research that raised these questions was taste aversion, first demonstrated by Garcia, Kimeldorf, and Koelling (1955), who demonstrated that the pairing of a novel flavor, saccharine, with gamma radiation, which has no immediate effects (although rats do appear to perceive it, because they can be awakened by small amounts; Garcia, Rusiniak, & Brett, 1977), results in the avoidance of the novel flavor by rats. Further research in the area of taste aversions has made clear the fact that even when the illness is imposed many hours after the novel flavor is ingested, learned aversion to the flavor still obtains

(Garcia, Kovner, & Green, 1970).

Although the taste aversion data have invalidated one of the conditions thought to be necessary for the occurrence of respondent conditioning, that of stimulus-stimulus temporal contiguity (Damianopoulos, 1984), they are still accepted as fitting the respondent paradigm, perhaps because taste aversion learning results from stimulus-stimulus pairings, the other necessary condition specified by Damianopoulos (1984).

More and more, researchers have come to similar conclusions: two-process learning theories are no longer viable in the face of consistently "anomalous" research results. "We have no assurance that the principles...are of general validity" (Rozin & Kalat, 1972, p. 93). "There is no such thing as a class of responses to be called respondent and another class...called operant" (Catania, 1971, p. 217). Noting the difficulties of distinguishing between respondent and operant conditioning on the basis of the procedures employed, Garcia, McGowan, and Green (1972) stated that "it is impossible to maintain the distinction on a functional organismic basis" (p. 14). The situation was perhaps best summed up by Hearst (1976), who stated that the retention of the respondent-operant distinction "is as much based on deeply ingrained philosophical and cultural beliefs as on research and theory in the psychology of learning" (p. 218).

Biological Constraints on Learning

At the same time they were contributing to the demise of two-process theories of learning, the experiments described above and many others gave rise to a new line of research. First called "preparedness" (Seligman 1970; Seligman & Hager, 1972), and later called "constraints on learning" (e.g., Hinde & Stevenson-Hinde, 1973; Shettleworth, 1972), research in this new area began to

focus on the ways that animals' biological inheritance interfered or interacted with the learning of certain types of behavior.

Besides the Williams and Williams (1969) finding that food deprived pigeons continue to peck lighted keys even when the pecks result in the omission of food, other experimenters provided examples of behaviors that were affected by animals' biology.

Bolles (1970, 1971), for example, proposed his model of species-specific defense reactions (SSDRs), innate behaviors elicited by threats to organisms that competed and were incompatible with the avoidance behaviors that the experimenters were attempting to teach (e.g., lever pressing to avoid shock versus freezing by the rat). Bolles later went on to state that species-specific defense reactions were all but unmodifiable (1975b), pointing out that the hungry rat "appears to be an excellent information processor, whereas the frightened rat often appears to be functionally decorticate" (Bolles, 1975a, p. 276).

In their well known "bright, noisy water" experiment, for example, Garcia and Koelling (1966) found that rats learned to avoid a flavor when it was paired with illness, but did not avoid it when it was paired with shock. In addition, when the drinking of water in the presence of flashing lights and loud noises was paired with either illness or shock, the rats avoided the water only in the shock condition.

Walters and Glazer (1971), who used gerbils as subjects, found that the use of a secondary punishment procedure, in which a tone had been paired previously with foot shock, resulted in the suppression of sand-digging but an increase in upright posturing. Similarly, Bolles and Riley (1973) found that freezing (i.e., immobility) by rats, though affected by punishment and avoidance

procedures, did not result from their learning of the experimental contingencies. Rather, it resulted from changes in the temporal patterns of elicitation.

In the area of grooming, mentioned above in relation to Thorndike, additional work has been carried out as well. Shettleworth (1973), who worked with hamsters, found that while behaviors such as bar pressing, scrabbling (when the hamster claws at the wall while hopping up and down as if it were trying to escape), digging, and rearing were very responsive to food reinforcement, face washing, scent marking, and scratching with a hind leg were not.

Charlton (1983), alternatively, found that he was able to "increase the rate" of grooming in golden hamsters with the use of fixed-interval schedules of reinforcement. By his own admission, however, the increase in rate (i.e., frequency) was accompanied by a decrease in the mean duration of each occurrence. Despite his interpretation, close examination of his third figure appears to indicate that the mean total amount of time the animals spent grooming remained constant across sessions. What Charlton obtained appears to be the same alteration that had been observed previously, that reinforced behaviors of this sort may become quite minimal in form while their frequency increases. That is, the responses, although increasing in frequency, are incomplete and abbreviated in form to such a degree that they give only a hint of their original complexity (e.g., Thorndike, 1911; Hogan, 1964; Konorski, 1967, all cited in Shettleworth, 1973).

In another type of organism, the three-spined stickleback (a small fish), Sevenster (1973) found that behaviors were either equally or differentially strengthened as a function of the reinforcer employed. Sevenster chose two behaviors, fighting, in which the male subject was allowed to "fight" with another male through a

glass partition, and courtship, in which the male was able to court a female through a glass partition, as reinforcers. The target behaviors that he chose to attempt to strengthen were swimming through a ring and biting a rod. Regardless, of which reinforcer was employed, the rate of swimming through a ring increased dramatically. Biting the rod, however, was increased only when fighting was the reinforcer.

The evidence gathered from these and other experiments dealing with constraints on learning appears to demonstrate that learning is modulated by "intrinsic" relations, that is, those that involve the structure of the organism in such a way that "the events themselves constrain the relation" (Rescorla & Holland, 1976, p. 180). It seems as if animals are predisposed to learn only those relations "that reflect true causal relationships in the environment" (Shettleworth, 1984, p. 175). More recent research has brought even this conclusion into question.

Constraints on Learning vs. Constraints on Performance

Although there is not yet enough evidence from which to draw firm conclusions, recent work suggests that constraints on learning, per se, may not exist. Instead, experimenters may have simply encountered constraints on performance. In other words, it cannot be assumed that an organism failed to learn associations between stimuli simply because the organism failed to perform the response that was expected by the experimenter.

For example, Parker and Smith (1981) re-examined the conclusions drawn by Garcia and Koelling (1966) in their "bright, noisy water" experiment and questioned whether rats encounter difficulty in forming flavor-shock, but not tone-shock, associations or whether, instead, the use of

ingestion as the dependent variable was "a curious way to evaluate an animal's ability to avoid trauma" (Parker & Smith, 1981, p. 335).

Using groups of rats and a two-way shuttlebox, Parker and Smith (1981) gave each subject 10 trials per day and delivered a footshock during five of them. Two of the groups were on a 23.5 hour water deprivation schedule and each trial commenced with the introduction of a drinking spout, through which tap water was available, which was withdrawn after 30 seconds on safe trials. Cues were lick-contingent for shock trials, and one of the groups was given a saline solution through the spout, while the other group was exposed to a tone. Although the differences between the two groups' performances were not statistically significant, it appears from the data that the flavor-cued subjects learned to avoid shock better than did the tone-cued subjects. Clearly, then, rats have no difficulty learning flavor-shock associations.

Comparing their results to those of Garcia and Koelling (1966), Parker and Smith point out that for rats, ingestion affects internal sensations, while locomotion and pedal contact with the environment affect foot sensations. They go on to state that "we should no more expect a rat to avert to the flavor of a substance that predicts footshock than to flee in terror from the sight of a moldy food pellet" (1981, p. 337).

The work of Jackson and his colleagues (Jackson & Allgeyer, 1985; Jackson, Allgeyer, & Hollingsworth, 1984; Jackson, Garbin, & Hollingsworth, 1984), described later in this paper, provides another example of the distinction between what rats learn and what they do.

It is within this historical context, in which theories of learning have been severely attenuated, animals have failed to learn some behaviors they were "supposed to" learn, and animals appear to be "prewired"

or "prepared" to perform other behaviors. Defensive burying has been recognized as another behavior that fails to fit the traditional mold.

A Fourth SSDR in Rats

For many years, it was assumed that the defensive repertoire of the rat was limited to attacking, freezing, and fleeing (Bolles, 1970, 1971). In contrast to this assumption, recent research has demonstrated the existence of a fourth defensive response. When rats are given a single shock through a stationary prod in the presence of some movable substratum, they do not attack or flee from the prod, nor do they freeze in its presence; they bury it (Pinel & Treit, 1978, 1979). This response, which potentially enables the rats to avoid future contact with the prod, is called defensive burying.

Although the burying phenomenon was first reported in an anecdotal fashion by Hudson (1950), it "was not the focus of rigorous quantification and control procedures" (Pinel & Treit, 1978, p. 708). Moreover, Hudson emphasized natural settings and adaptive behavior when most psychologists were concerned with strictly controlled studies of learning processes (Pinel & Treit, 1978). As a result, Hudson's discovery was generally not noticed and, therefore, not cited. It was not until 1978 that Pinel and Treit published their series of four experiments which demonstrated that the avoidance of sources of aversive stimulation through burying plays a prominent role in the rat's defensive repertoire.

The Nature of the Burying Response

Bolles (1970, 1971) has argued that in order to fully understand an organism's capacity to learn avoidance responses, it is necessary to have a thorough knowledge of that organism's species-specific defense reactions (SSDRs). Drawing on most of the literature concerning rats, he concluded that their defense reactions were limited to freezing, fighting, and fleeing.

Based on standard laboratory procedures, Bolles' conclusions were well supported by data obtained from a wide variety of test environments and situations within those environments. One feature common to all of those test environments, however, was that the floor of the experimental apparatus consisted of a rigid, metal grid, through which shock could be delivered and urine and feces could drop. Unlike natural environments, there was usually nothing on the floor which could be moved or manipulated (Pinel & Treit, 1978).

An early exception to this standardized laboratory environment was employed by Hudson (1950) in a study that was apparently overlooked by Bolles. In a series of investigations of one-trial learning in rats, Hudson's testing took place in the animals' home cages. The front half of each cage consisted of a galvanized iron platform and the rear half was covered with wood shavings.

Hudson's basic procedure was to remove the food from the cage prior to the experiment and to place into the cage a three-inch square of striped bakelite, through the center of which protruded a small food holder. The metal food holder was wired to one terminal of a shock circuit and the iron platform was wired to the other. Hudson was then able to deliver a shock to the animal while it ate from the food holder, before temporarily removing the

animal from its cage. The animal was returned to the cage after the cage had been returned to its original condition.

After placing the rat back in the cage, which was in its experimental configuration, test trials were carried out. Ninety-five percent of the animals pushed, carried, and packed wood shavings toward and over (i.e., buried) the bakelite stimulus. These activities decreased over successive trials.

The effect of Hudson's work on the avoidance conditioning literature has been negligible. The reason for this, as mentioned previously, may lie in the fact that burying "was not the focus of rigorous quantification and control procedures" (Pinel & Treit, 1978, p. 708), and because Hudson emphasized adaptive behavior at a time when most psychologists were concerned with strictly controlled studies of learning processes (Pinel & Treit, 1978). It was not until almost thirty years had passed that further work in this area was initiated.

In 1978, Pinel and Treit, with a series of four experiments, demonstrated that the avoidance of sources of aversive stimulation through burying plays a prominent role in the rat's defensive repertoire. In their first experiment, Pinel and Treit (1978) preexposed 120 rats to the test chamber in groups of five for 30-minute periods over four consecutive days. On the fifth day, rats in one group (n=60) were individually placed in the chamber, into which a wooden prod had been inserted above the bedding material. When each rat first touched the prod with a forepaw, a shock was delivered through the two uninsulated wires that were wrapped around the prod. The animal was then removed from the chamber. Rats in the second group (prod controls, n=30) were treated in the same manner but were not shocked, and rats in the third group (no-prod controls, n=30) were individually placed in the chamber

for a few seconds with no prod present. Subjects in each of the treatment conditions were then returned to the chamber for an individual, 15-minute, shock-free test either 10 seconds, five minutes, five hours, or 20 days later. An analysis of variance yielded statistically significant differences for duration of prod burying regardless of the test interval. The greatest amount of burying was exhibited by the shocked animals. Identical results were obtained when the means of the ratios of the highest pile divided by its distance from the prod were compared.

In their second experiment, Pinel and Treit (1978) inserted the prod into the rats' home cages after the rats had been preexposed to the test chamber as in Experiment 1. Ten animals were shocked and ten were not shocked. One minute after contact with the prod in the home cage, each rat was tested with the prod in place in the test chamber. Again, the shock subjects spent more time burying than did the control subjects, and their ratios of pile height to distance from the prod were also greater. This demonstrated that rats shocked in one setting will bury the source of aversive stimulation when exposed to it in another setting.

Experiment 3 (Pinel & Treit, 1978) was carried out in order to determine if shock in and of itself was a sufficient condition for prod burying. Thirty rats were preexposed to the test chamber and were briefly placed in the test chamber with the prod mounted on the wall. One half of the animals were shocked through the grid floor of the chamber while they were in it. No statistically significant differences were obtained between the groups, and no burying of the prod was observed in either of them.

Pinel and Treit (1978) carried out their fourth experiment in order to demonstrate that the burying responses observed in the first two experiments were

directed at the prod because the prod was the source of aversive stimulation, rather than because the prod was the only novel stimulus in the setting. In this experiment, two identical prods were present on the fifth day, one at each end of the chamber. Each of the ten subjects was allowed to touch both of the prods before a shock was delivered through one of them (randomly predetermined). Each of the rats spent time burying the prod through which it had been shocked; and only one rat briefly attempted to bury the other prod, but only after it had completely buried the shock prod.

To summarize, the four experiments by Pinel and Treit (1978) clearly demonstrated that burying is a defensive response in that, first, it occurs in response to aversive stimulation and, second, it is directed adaptively at the source of aversive stimulation in such a way as to afford the animal potential protection from it. Additionally, there was not a single occurrence of the three defensive responses to aversive stimulation that were described by Bolles (1970, 1971), that is, periods of immobility lasting more than a few seconds, attempts to escape from the test chamber, or aggression directed toward the prod. Defensive burying should, therefore, be included in the rat's repertoire of defensive behaviors.

The burying response is unlike the digging behaviors that are usually observed in the rat. It is an unusually stereotyped response. As Pinel and Treit (1979) described it:

Each burying sequence typically began with the rat facing the shock prod from a distant part of the apparatus. Then the rat moved directly toward the prod pushing and spraying a pile of bedding material ahead with rapid shoveling movements of its snout and alternating pushing movements of its forepaws (p. 392).

Types and Magnitude of Aversive Stimuli

Besides being elicited by shock (Hudson, 1950; Pinel & Treit, 1978, 1979), defensive burying can be elicited by a number of other stimuli, implying that they, too, are aversive. Silverman (1978), though not investigating defensive burying, per se, ran an experiment in order to assess the effects of tobacco smoke on rats, hamsters, mice and guinea pigs. During daily sessions, the rodents were placed into glass cylinders into which diluted cigarette smoke was delivered through plastic tubing. Silverman found that six of eight rats, ten of twelve hamsters, and ten of sixteen mice responded by pushing and packing feces in and around the air inlet. One hamster did this so effectively that it suffocated. None of the guinea pigs exhibited these behaviors.

A series of experiments run by Terlecki, Pinel, and Treit (1979) demonstrated that defensive burying in rats could be elicited by a blast of air delivered through a polyethylene tube, by being struck by a mouse trap with its spring loosened, and by the flash of a flashbulb. Further work with flashbulbs has shown that the elicitation of burying is a function of the heat generated during the flash, rather than the light itself (Davis, Whiteside, Dickson, Heck, & McKnab, 1982).

Noxious Foods

Early research suggested that noxious foods are also buried by rats. Wilkie, MacLennan, and Pinel (1979) ran a series of experiments in which two water spouts were inserted into the chambers. For the first seven days, water was available through both spouts for thirty minutes each day. Afterwards, the water bottles were removed and a bottle filled with a 50/50 solution of sweetened

condensed milk and water was presented through a striped spout for the same thirty-minute period. Immediately following this period, during which each subject consumed some of the milk, each animal was injected with a lithium chloride solution (which caused illness) and returned to the chamber in the presence of the milk spout and a water spout. All of the animals buried the milk spout, none buried the water spout, and no more milk was consumed. They also did not bury a spout containing a novel saccharine solution the next day.

The above procedure was then repeated, but without induced toxicosis. In this case, the striped spout contained undiluted Tabasco pepper sauce. All four rats buried the Tabasco sauce tube but not the concurrently available water tube (Wilkie et al., 1979).

Poling, Cleary, and Monaghan (1981) replicated these experiments and also found that rats will bury a Tabasco sauce tube when it is presented with a water tube. They also induced toxicosis following milk consumption, but used d-amphetamine sulfate rather than lithium chloride. Again, the rats buried the milk tube and not the water tube.

More recent research in the area of noxious food burying, however, has yielded some very interesting results. An extensive series of well controlled experiments by Jackson and his colleagues (Jackson & Allgeyer, 1985; Jackson, Allgeyer, & Hollingsworth, 1984; Jackson, Garbin, & Hollingsworth, 1984) has revealed that it is not the noxious food, per se, that the rats bury.

In an attempt to identify the associative nature of the burying response as it relates to foods (i.e., which stimulus aspects of the foods function as burying elicitors), Jackson, Garbin, and Hollingsworth (1984) found that they were unable to obtain burying following the pairing of lithium chloride with either saccharin or

salt solutions. This result obtained even after the rats had experienced two pairings of the solutions with the lithium chloride prior to being tested for burying. Hypothesizing that the possible reason for the success of Wilkie et al. (1979) may have been due to either some novelty effect of the milk and water solution that they used, the simultaneous encountering of the illness and the solution, or to a combination of both, Jackson, Garbin, and Hollingsworth (1984) closely replicated the procedures employed by Wilkie et al. (1979), using a saccharine rather than milk solution. No burying occurred.

In order to determine whether it was possible that their apparatus and/or procedures were incapable of producing burying, three more brief experiments were run in which toxicosis was paired with tabasco sauce or a sweetened condensed milk solution. In each of these cases, burying was obtained. This pattern of results suggested that toxicosis-induced burying was a function of something more than a simple pairing of toxicosis with novel gustatory stimuli. Thus, another experiment was run.

Four groups of rats were compared. Two of the groups had lithium poisoning paired with a banana extract flavored solution and two had the poisoning paired with a saccharine solution. For each of the groups, saline injections were paired with whichever of the two flavors had not been paired with toxicosis. During testing, the groups were exposed to either the flavor that had been paired with toxicosis or the flavor that had been paired with the saline injection. Of the four, the only group that exhibited any burying was the one that had poisoning paired with the banana flavor and was tested with the banana solution present. Thus, although there was a confounding of taste and odor cues in the banana solution, it was clear that learned taste aversions were not

sufficient to bring about burying. Olfactory cues also played some role.

In the succeeding set of experiments, peripheral anosmia was employed by Jackson, Allgeyer, and Hollingsworth (1984) in an attempt to determine the role of olfactory stimuli in defensive burying. Pairing a milk solution with lithium chloride-induced toxicosis, two groups were first compared. For one group, peripheral anosmia was induced after the milk-toxicosis pairings on the day preceding the burying trials through the infusion of a 5% zinc sulfate solution into each nostril. The nostrils of the other group were infused with a saline solution. During the first test, only the saline-infused group buried the spout containing the milk solution, although both groups of rats avoided drinking the solution. The second test employed was simply a replication of the traditional shock prod experiments. This was done in order to be sure that the zinc sulfate did not in some way inhibit burying, itself. Both groups buried the prod. For the third test, the treatment of the two groups' nostrils was reversed. Again, neither group drank the solution and only members of the saline-infused group buried the spout.

The second experiment was a replication of the first, using the banana flavored solution instead of the milk and, since the first experiment had made clear the fact that zinc sulfate-induced anosmia did not interfere with the burying response, the shock prod phase was omitted. The results were the same in that, during each of the two tests for burying, only the animals that retained their sense of smell buried the spout.

Because the first two experiments appeared to substantiate the hypothesis that the ability to perceive odors played a critical part in toxicosis-induced burying, the third experiment was run in order to determine whether

the same was true for the burying of tabasco sauce. It was. Therefore, "defensive burying of appetitive events depends upon olfactory cues while burying of shock-related events is controlled by other types of stimuli" (Jackson, Allgeyer, & Hollingsworth, 1984, p. 184).

Having established that the burying of appetitive (i.e., food related) stimuli depends on olfactory cues, another series of experiments was conducted by Jackson and Allgeyer (1985) in order to test their view that "aversive taste cues suppress consumption while odors affect nonconsummatory activities" (Jackson & Allgeyer, 1985, p. 316). Additionally, they wanted to rule out an alternative hypothesis. Because compound stimuli consisting of both gustatory and olfactory cues are more easily conditioned than are gustatory cues alone in taste aversion experiments, odorous solutions, such as milk or banana extract, may function as more potent conditioned stimuli than relatively nonodorous solutions, such as saccharine.

The first experiment tested this by comparing groups of rats that had received either a saccharine solution or plain water prior to the lithium chloride-induced toxicosis. During testing, all animals had two drinking tubes present. One tube contained plain tap water, and the other contained one of two solutions, either a saccharine solution or a saccharine solution to which banana extract had been added. While the animals poisoned with saccharine drank very little of the saccharine solution, compared to the animals that were poisoned without the saccharine pairing, only the poisoned animals tested with the combined solution buried the spout.

The possibility still existed, however, that those results were due to an interactive effect of poisoning and a neophobic (i.e., fear of novelty) reaction to the banana compound. If that were the case, rats would be expected to bury any toxicosis-conditioned flavor combined with

some novel solution. In order to test this, two groups of rats were again poisoned. This time, poisoning was paired with saccharine for one group and with a saline solution for the other.

The rats were then tested for burying with either a plain saline solution, a combined solution of saline and rose water, or a combined solution of saline and saccharine. The only group that buried the spout was the group tested with the combined solution of saline and rose water, indicating that novelty combined with toxicosis was not sufficient to evoke burying. The combined rose water solution, however, may have been a more potent stimulus compound than the other combined solution, and may have elicited neophobia more readily than did the other. No prior experiment had tested directly the dependence of burying on olfactory cues.

In the third experiment, groups of rats were compared in which both had toxicosis paired with saccharine. Both groups were also tested with a combined solution of saccharine and banana extract. The difference was that peripheral anosmia was induced in one group through the injection of zinc sulfate into its members' nostrils. During the burying test, only the group that was not anosmic buried the spout.

The fourth experiment was run for two purposes. The first was to replicate systematically the previous work; the second was to determine why rats bury a previously conditioned solution to which an odorous substance has been added. The possibility existed that the addition of the odorous substance resulted in higher order conditioning to the odor, which then controlled burying.

After conditioning a number of rats to saccharine, two tests of burying were carried out, six days apart. During the first test, animals exposed to a compound solution of saccharine and banana extract buried the

spout, while animals exposed to simple saccharine or banana solutions did not bury it. During the second test, the primary comparison was between the groups of animals that had buried the spout during the first test: one group was exposed to the banana solution and one group to the saccharine solution. Only the group tested with the banana solution buried the spout, indicating that higher order conditioning had occurred during the first test, when the saccharine and banana had been combined.

Overall, Jackson and his colleagues (Jackson & Allgeyer, 1985; Jackson, Allgeyer, & Hollingsworth, 1984; Jackson, Garbin, & Hollingsworth, 1984) have established that when rats bury solution sites, they do so as a function of the occurrence of higher order conditioning between the flavor and the odor of the solution. Additionally, the demonstration that rats will avoid the consumption of all solutions paired with toxicosis, but will bury only those that have distinct olfactory qualities, suggests that gustatory stimuli are more highly associable with processes that affect consummatory behavior than they are with those that affect the performance of other behaviors. This indicates that similar higher order conditioning processes may be necessary to separate other learning and performance distinctions.

Shock Intensity and Controllability

Additional work has been carried out in order to determine the effects of varying shock intensities and those of the "controllability" of preshock. Treit, Pinel, and Terlecki (1980) used five groups of fifteen rats to replicate systematically the original study by Pinel and Treit (1978). The difference was that rats in each group received a different intensity of shock, ranging from a no-shock control group through a ten milliamps (mA) shock group. The results were that as shock intensity

increased, so did the durations of burying and the heights of the piles of bedding. The lone exception was that neither of the dependent measures was as great for the 10 mA group as for the 6.5 mA group.

Williams (1987) ran an experiment in which preshock controllability affected the burying response. Following four days of habituation to the burying test chamber, 24 rats were assigned randomly on the fifth day to one of three groups, escapable shock (E), yoked-inescapable shock (Y), or restrained/no shock (R). Each of the rats was treated individually in a wheel-turn box. Subjects in Group E received 80 trials of escape training, in which shock was terminated when the rat completed a one-quarter turn of the wheel. Group E rats, therefore, had control over shock termination. Rats in Group Y received shocks of the same number, intensity, and duration as the rats in Group E, but were unable to escape them. Rats in Group R were restrained in the same wheel-turn boxes for 90 minutes, but received no shock.

The rats were tested for burying, following prod-shock, on the sixth day. Williams (1987) found statistically significant differences between the burying durations exhibited by rats in Group Y and those of the rats in the other two groups. The mean burying durations of Group Y were less than one-quarter of those of Groups E and R, demonstrating that a history of inescapable shock attenuates the burying response. Another experiment run by Williams (1987), described in the following section, supported this finding.

Summary

Overall, it appears that rats will bury any object which is the source of a tactile aversive stimulus, but the burying of foods is a function of higher order conditioning between gustatory and olfactory cues. In

addition, from the only work in this area carried out to date, it seems clear that the amount of burying elicited by tactile aversive stimuli is attenuated by inescapable prior exposure to the stimulus, and is a direct function of the intensity of the unconditioned aversive stimulus. The shape of this functional relation remains to be determined.

Environmental Variables That Affect Burying

In the work by Pinel and Treit (1978), burying was elicited by a shock in a relatively small chamber (44 x 30 x 44 cm) with a substratum of ground corncob. (1950) had used a substratum of wood shavings, and the obvious questions to arise revolved around two points. The first was whether other substrata would be employed similarly by rats, and the second was whether the burying was being "forced" by the size of the chamber. That is, the burying may have occurred because the chamber size prevented any other escape from the aversive stimulus.

The first question was answered by Pinel and Treit (1979). Employing three groups of hooded rats in the chambers described above, the experimenters provided the subjects in each group with a different substratum; either ground corn cob, sand, or wooden blocks (1.0 x 1.6 x 2.4 cm). All but one animal used the available material to bury the shock prod.

When the sand was used, the rats' burying responses involved the same topography that Hudson (1950) described in his paper. When the blocks were used, the nine animals that buried the prod all used similar pushing motions with their snouts and forepaws to move them across the chamber.

Additionally, seven of the nine actually picked up the blocks with their teeth and placed them in a pile over the prod with their teeth and forepaws. These behaviors were again observed in another group of rats when all of the blocks had been placed at the end of the chamber opposite the shock prod (Pinel & Treit, 1979). These results were replicated by Whillans and Shettleworth (1981).

The second question, whether burying is a function of the lack of opportunity to escape, was addressed by Pinel, Treit, Ladak, and MacLennan (1980), who tested four groups of rats in one of four chambers; small (25 x 20 cm), medium (50 x 40 cm), large (100 x 60 cm), and very large (200 x 80 cm). Each group was subdivided into shock groups and no-shock control groups. Within each group, the shocked rats engaged in more burying than did the controls, and both the duration of burying and the resultant heights of accumulated piles of bedding appeared to be a function of chamber size; the longest burying durations and the highest piles were obtained in the smallest chamber.

In a second experiment, two groups of rats were tested in the medium chamber, but a divider with a ten cm gap was placed at the midpoint for one group, resulting in two 25 x 50 cm compartments. The animals tested with two compartments spent less time burying and accumulated smaller piles of bedding than did the animals tested in the single, larger compartment, although only the difference in burying durations was statistically significant. It is worth noting that the authors failed to provide data regarding where the rats spent the majority of the time in which they were not engaged in burying. Did they, spend this time in the back compartment, thus avoiding visual contact with the aversive stimulus, or not?

Poling et al. (1981) also tested three rats in large

chambers (85 x 55 cm for two and 65 x 45 cm for one) using Purina Rat Chow pellets, marbles, and a taste aversion test in which sweetened condensed milk was paired with lithium chloride injections. In this study, burying occurred in all cases, with no attenuation due to increased chamber size.

Williams examined the effect of another environmental variable on burying, the presence of odors from stressed conspecifics. Williams (1987) first exposed 32 rats to the test chamber for 30 minutes per day for four days: one day in groups of four, two days in groups of two, and one day individually. On the fifth day, all the rats were restrained individually in Plexiglas tubes, and half of them received 80 mA, 5-second inescapable shocks to the tail. On the sixth day, five "odor-donor" rats received five mA, 5-second shocks in a shuttlebox. They were treated individually and, following their removal, the bedding material from below the shuttlebox, which contained the odorous urine and feces of the five rats, was collected.

The burying test used a wooden dowel, wrapped with wire, as a shock source. Half of the preshocked rats and half of the nonshocked rats were tested with the soiled, odorous bedding included in the burying test chamber, and half of each group was tested with only unsoiled bedding. The experiment involved four groups of rats: Group PS/SO had been preshocked and was tested with the stress odors present, Group PS/NSO had been preshocked and was tested with no stress odors, Group NS/SO had no preshock and had stress odors present, and Group NS/NSO had no preshock and no stress odors.

Williams (1987) found that both preshock and the presence of conspecific stress odors attenuated burying to a statistically significant degree, especially when the two were combined. The most burying was exhibited by

Group NS/NSO, followed in order by Group PS/NSO, Group NS/SO, and Group PS/SO.

The evidence to date indicates that the burying response is extremely robust (Sidman, 1960); one that occurs regardless of the substratum or of the size of the chamber. While it is clear that enlarging the chamber attenuates the burying response to some degree, the magnitude to which this effect occurs is unclear, since the altered chambers have varied more in the area of square centimeters of floor space than in actual distances from the prod that the animals were able to remove themselves. Burying is also attenuated by the presence of stress odors from shocked conspecifics.

Learning and Discrimination of Relevant Stimuli

As Pinel and Treit (1978) demonstrated, rats shocked through one of two identical prods bury only the prod through which the shock was delivered. This result was also obtained with the three substrata used in their later work (Pinel & Treit, 1979). Similar results have been obtained by other experimenters (Whillans & Shettleworth, 1981).

When prods of two different colors were present, the subjects spent more time burying the prod through which the shock was delivered (Pinel, Hoyer, & Terlecki, 1980). The same discrimination was made when the source of the aversive stimulus was an airblast tube, a flashbulb, or a mousetrap (Terlecki, et al., 1979), or when one of two drinking spouts was either the source of a noxious food or a novel food paired with induced toxicosis (Poling et al., 1981; Wilkie et al., 1979).

Additional and more complex studies of discrimination in defensive burying have also been undertaken. In their first of a series of experiments, Arnaut and Shettleworth (1981) compared the burying responses of two groups of subjects when those in one group were shocked by a prod and those in the other group received an equivalent grid shock while touching the prod, before being transferred to an identical chamber with a sawdust covered floor. The animals in both groups buried the prod.

Two other groups were compared next. The subjects in one group received a grid shock the first time that they reared on their hind legs at least one minute after touching the prod, while the others received the grid shock at equivalent times with no prod present. Both groups were tested with the prod in place and, in this case, no consistent burying was exhibited by any of the subjects.

The third experiment carried out by Arnaut and Shettleworth (1981) was identical to their first, except that the prod, which was on the left wall of the chamber during shock delivery, was on the right wall during testing. In this instance, although the animals in the two groups spent equivalent amounts of time engaged in burying, the prod-shocked group used more of this time burying the prod. Much of the behavior of the grid-shocked group was directed at the walls of the chamber, indicating that the grid-shocked subjects did not learn the specific prod-shock association that was learned by the prod-shocked subjects.

Other discrimination experiments were carried out by Pinel, Treit, and Wilkie (1980). In their first experiment, a 2 X 2 factorial design (see Table 1), subjects were shocked by either a black prod or a white prod placed at either the back or the front of the chamber. Four groups were then tested with the same prod in the same

position, the same prod in the opposite position, a different prod in the same position, or a different prod in the opposite position.

Although the animals in all four groups engaged in more burying than a fifth no-shock control group, a difference that was statistically significant, the most burying and the highest piles of bedding were recorded for the subjects tested with the same prod in the same position as when they were shocked. Changing either the prod color or its location led to a marked decrease in burying, although changing both did not produce a much greater decrease than changing only one.

Table 1

The Experimental Design Employed by Pinel, Treit, & Wilkie (1980)

	Same Prod	Diff Prod
Same Pos.	Same Prod Same Pos.	Diff Prod Same Pos.
Diff Pos.	Same Prod Diff Pos.	Diff Prod Diff Pos.

Also of interest was the behavior of eight of the twenty animals that were tested with the prod in the opposite location. After burying the prod, each of these animals returned to the prod's previous location at the opposite end of the chamber and sprayed the substratum at the hole through which the prod had previously been inserted. No burying was directed toward identical holes in the chamber's sides.

These attempts to bury the hole through which the prod had been inserted may be related to the behavior of

wild rats, which seal off burrow entrances in an apparent attempt to repel intruders (Calhoun, 1962, cited in Pinel, Treit, & Wilkie, 1980), and are similar to the behavior of Silverman's (1978) rodents, which used feces to block the inlet through which smoke was passed.

In the second experiment, the rats were shocked by either the black or the white prod when one of the prods was present at each end of the chamber. The rats were then tested with the prods in the same position or with the positions of the prods reversed. Although the subjects in both groups engaged in equivalent amounts of burying, subjects in the same-position group directed their burying almost exclusively toward the shock prod, while those in the reversed-position group divided their time equally between both prods, often vacillating between the two during the burying, itself.

In their third experiment, Pinel, Treit, and Wilkie (1980) tested the durability of stimulus control by shocking the rats under the same conditions as in the previous experiment before removing them from the chamber. The six groups of subjects were then returned to the chamber for testing at 30 seconds, five minutes, one hour, eight hours, 24 hours, or seven days later, with the prods in the same positions. The rats in every one of the groups exhibited more burying, both in duration and accumulated piles, directed at the shock prod than at the control prod, although the difference was not statistically significant for the seven-day group.

The results of these experiments demonstrate that from a single pairing of the stimulus source and the unconditioned aversive stimulus, specific features of the stimulus source as well as its location are learned.

Intersetting Transfer

Experiments involving further alteration of the shock prod location have been carried out as well. Pinel and Treit (1978) ran an experiment in which the rats were shocked by the insertion of the prod through the wire mesh of their home cages. When tested in a chamber one minute later, the rats buried this prod.

Goldberg and Cheney (1982b, Exp. 1) used a translucent prod to deliver shocks to six rats in one chamber and tested the rats in another chamber, employing a different, but matching prod. For three of the rats, the test prod was back-lighted by a high-intensity desk lamp. The prod remained dark for the other three, as the shock prod had been. All of the rats buried the new prod and, although the groups were too small to obtain a statistically significant difference, the rats tested with the dark prod each engaged in longer durations of burying and accumulated higher piles of bedding over the prod than did the rats tested with the lighted prod.

The fact that all of the rats buried a second matching prod in a second setting demonstrated conclusively that prod identification occurs through visual and/or olfactory properties of the prod, itself, and not through any odors deposited by the rats onto the prod.

The difference in the amounts of burying of the lighted and unlighted prods in the Goldberg and Cheney experiment extends the findings of Pinel, Treit, and Wilkie (1980), who used either a black or a white prod to deliver the shock and either the same or the opposite colored prod during the test phase. They, too, found that altering the brightness of the prod, regardless of the direction, attenuated the burying response, but with a

much greater and statistically significant difference. There may have been a confounding variable that augmented this difference, however. The rats of Pinel, Treit, and Wilkie were tested with the same prod or a matching (except in color) prod, whereas the rats of Goldberg and Cheney were all tested with a different prod that varied in brightness, alone.

In an extension of this work regarding the stimulus properties of the prod, Goldberg and Cheney (1982b, Exp. 2) again shocked rats in one chamber with the translucent prod, which was lighted this time, and tested them in a second chamber. During the test, another prod, one that matched the first but was unlighted, was located at one end of the chamber and a lighted translucent window was located at the other end. Not one of the rats buried either stimulus. Although these results appear to indicate that the shock source is visually identified as a unitary stimulus complex, no definite conclusions can be drawn from this experiment due to the small number of rats tested ($n=3$) and the fact that a different preexposure sequence was employed, as well. Oberdieck and his colleagues (Oberdieck & Cheney, 1982; Oberdieck & Tarte, 1981; Tarte & Oberdieck, 1982) have demonstrated that differences in preexposure to the shock-test setting and contextual changes between the shock and test periods can lead to differences in the resultant burying response, including differences in its duration.

Respondent Conditioning

In addition to the use of unconditioned aversive stimuli, burying experiments also have been carried out

with the use of classically conditioned stimuli. Davis, Grady, Klaess, Petty-Zirnstein, and Tramill (1983) paired a light with a grid shock each time their rats were placed into the chamber. These light-shock pairings were carried out ten times per day for two consecutive days. On Day 3, bedding material was placed in the chamber and, as soon as each rat came close to the light (nose approximately 1 cm away), the light was illuminated. A substantial amount of burying was directed at the light by the rats in the CS-UCS correlated condition and none occurred in the other three groups: uncorrelated CS-UCS presentations, US presentations alone, or UCS presentations alone.

Davis et al. (1983) ran a second experiment in which two CS-UCS correlated groups were used. During training, the rats in one of these groups could avoid the shock by jumping onto a platform. When tested on Day 3 with the safe area blocked, the rats in both groups directed their burying toward the light and there were no statistically significant differences between the groups in either burying duration or heights of bedding accumulation.

In a systematic replication of Davis et al. (1983), Goldberg and Cheney (1982b, Exp. 3) gave four trials per fifteen-minute session in which a Plexiglas window was illuminated for 10.5 seconds and, concurrent with the last half-second, delivered a grid shock. Immediately following the tenth daily session of CS-UCS pairings, each rat was placed into a second chamber that contained wood shavings and a translucent Plexiglas prod. Upon each animal's first paw-to-prod contact, the prod was lighted from the rear for twenty seconds. During the succeeding test periods, no subject exhibited any burying behavior. It is not clear why this result was obtained. However, the lack of a control group subjected to the same test in the conditioning chamber leaves open the possibilities that either the sequence of CS-UCS pairings was

insufficient for conditioning or that classically conditioned stimuli lack the power to elicit burying in second setting.

Another well controlled experiment in this area was carried out by Spetch, Terlecki, Pinel, Wilkie, and Treit (1982), who employed a single conditioning session in which each rat in the experimental group received six UCS-CS pairings. Each of the first five pairings consisted of a brief shock to the back, which was followed one second later by the insertion of a prod into the chamber for five seconds. On the sixth pairing, the prod was left in the chamber for two minutes, after which the rat was removed. Five minutes later, the rat was returned to the chamber with the prod in place. Rats in this backward conditioning group spent as much time burying the prod as did rats in the forward conditioning (CS-UCS) group, and both groups engaged in a greater amount of burying than did three control groups--a difference that was statistically significant.

The results of these three studies demonstrate that although the elicitation of burying by classically conditioned stimuli can occur, further research is necessary to determine the conditions that are necessary and sufficient for such occurrence.

Inter- and Intraspecies Replications

Rats

A number of investigations have explored the possibilities that other species of rodents might also engage in defensive burying and that interstrain differences might exist. Interstrain differences have

been obtained consistently. However, the direction of these differences has been inconsistent. For example, in comparisons of Long-Evans hooded rats with albinos, McKim and Lett (1979) found that the hooded rats buried more than did the Sprague-Dawley albinos, whereas Goldberg and Cheney (1982a) obtained similar differences in the opposite direction.

Comparisons of other albino strains with the Long-Evans hooded strain have been similarly inconsistent. Whereas Treit, Terlecki, and Pinel (1980) found that the Long-Evans rats buried less than either Wistar or Fischer albinos, with the Fischer group burying the most, the Long-Evans rats of Tarte and Oberdieck (1982) buried more than did their Wistar albinos. One difficulty in comparing these studies directly is that different preexposure sequences were employed in each.

Treit, Terlecki, and Pinel (1980) also ran an experiment in which they compared the burying behavior of male and female Long-Evans hooded rats that were either 30, 60, or 90 days old. While there were no substantial sex differences, statistically significant differences were obtained for burying durations across age. The most burying was observed in the 60-day-old subjects and the least in the youngest subjects.

Mice

Insofar as other species of rodents are concerned, mice have exhibited the burying response consistently (Davis, Whiteside, Heck, Dickson, & Tramill, 1981; Harder & Maggio, 1983; Maggio & Harder, 1983; Treit, Terlecki, & Pinel, 1980); interstrain differences have also been obtained (Harder & Maggio, 1983; Maggio & Harder, 1983; Treit, Terlecki, & Pinel, 1980).

Hamsters

In studies of hamsters, Whillans and Shettleworth (1981) failed to obtain shock prod burying regardless of whether sawdust or wooden blocks were used, despite the fact that the hamsters were observed to carry the blocks in their mouths during habituation and testing. In a second experiment, these investigators compared the behavior of hamsters shocked by one of the two prods present with that of hamsters that were not shocked. Although none of the hamsters exhibited any burying, the shocked subjects waited a longer time before recontacting the shock prod, but not the other prod, than did the control subjects. The shocked subjects also touched both prods less than the control subjects did.

Gerbils

Initial work with gerbils indicated that defensive burying was not a part of their response repertoire (Davis, Whiteside, Heck, Dickson, & Tramill, 1981; Treit, Terlecki, & Pinel, 1980), but later work by Davis, Moore, Cowan, Thurston, and Maggio (1982) demonstrated that gerbils will bury a shock prod if the chamber is round, rather than rectangular. Also observed in this study was that, unlike the burying topography displayed by rats and mice, the gerbils' burying response involved the use of the hind feet to kick the substratum toward the prod.

Summary

Overall, it is clear that differences in defensive burying are found both between and within species. Intra-species differences have been observed in both rats and mice, but the differences obtained are not consistent in direction across laboratories. Differences between species are such that, although rats, mice, and gerbils have all exhibited defensive burying behavior, hamsters

have not. Additionally, burying in gerbils differs topographically from burying in mice and rats and the burying behavior of gerbils is a function of chamber shape. It is interesting to note, however, that hamsters are able to make the same prod discriminations that are made by rats and most strains of mice, and that they did engage in feces-packing in Silverman's (1978) work. It may be that, as it was with gerbils, the right environmental conditions have not been found yet which would permit the observation of burying by hamsters.

Conditioned versus Unconditioned Burying

The fact that the burying response can serve as a defensive response has been demonstrated clearly. First, it occurs in response to aversive stimulation and second, it is adaptively directed at the source of the stimulation in such a way as to afford the animal potential protection from it (Pinel & Treit, 1978). Not all burying, however, is elicited by an aversive stimulus.

McKim and Lett (1979) noticed this in their initial attempt to compare the post-shock burying of hooded rats with albino rats. As it turned out, seven of the hooded rats buried the prod during the five-minute preexposure period, while none of the albinos did so. Even Hudson (1950) mentioned that some of his rats buried the stimulus upon first being exposed to it, but he failed to provide supportive data.

In a systematic replication of their first experiment, McKim and Lett (1979) extended their one-session preexposure period to an hour and delivered the shock during a second session held the following day. Eleven of

the 16 hooded rats and five of 16 albinos buried the prod prior to receiving a shock, and all of the animals except one buried the prod following the shock, with the highest piles of sawdust being left by the hooded rats.

Suspecting that the differences between their results and those of Pinel and Treit (1978) were due to the four-session habituation period with no prod present that Pinel and Treit used, McKim and Lett (1979) used four groups of ten albino rats in a 2 x 2 design. Two groups of rats received 30-minute habituation sessions with the prod absent for four consecutive days (habituated), while two groups were left in their carrying cages in the same room for equal intervals (unhabituated). No manipulations were carried out on the fifth day. On the sixth day, each rat was placed into the chamber with the prod present and shocks were delivered to half of each of the two groups. Among non-shocked rats, none of those habituated to the chamber buried the prod, while five of the ten unhabituated rats buried it. All of the shocked rats buried the prod, with the highest piles of bedding material being left by the unhabituated rats. Within both conditions of preexposure, shocked rats engaged in more burying than did non-shocked rats. Overall, it is clear that burying can be conditioned (i.e., elicited by an aversive stimulus) or unconditioned (i.e., spontaneous, and probably related to neophobia), and that habituation attenuates both the probability and the magnitude of burying, regardless of whether an aversive stimulus is applied.

Additional work in the area of conditioned and unconditioned burying was carried out by Terlecki et al. (1979). Following four days of habituation sessions in an empty chamber, groups of ten hooded rats received one of four treatments: a shock from a prod, an airblast from a polyethylene tube, a flash from a flashbulb, or a smack

from a mousetrap with its spring loosened. For each group of ten rats, there was a control group of five which were exposed to the same source of aversive stimulation but did not receive the stimulation itself. In the groups exposed to the shock prod and airblast tube, only the animals that experienced the aversive stimulation buried the object, while almost all of the other animals buried the flashbulb and the mousetrap, regardless of their experience with them.

In their second experiment, Terlecki et al. (1979) used the flashbulb and mousetrap as they had in their first experiment, except that these devices were present during the four habituation sessions. The results in this case were that none of the control rats buried the object during the fifth-day test period, and the experimental rats buried it only after the aversive stimulus had been delivered.

While habituation to the stimulus source does, apparently, attenuate the burying response, questions remain as to whether unconditioned burying by rodents always serves some defensive function. While this is clearly the case when squirrels kick sand at snakes (Owings & Coss, 1978) and when Silverman's (1978) rodents blocked the smoke inlet, it is less well-defined in other situations, such as when gophers bury traps that have been placed in their burrows (Hudson, 1950).

In an attempt to clarify this point, Pinel, Hoyer, and Terlecki (1980) employed an additional dependent measure, approach-avoidance behavior. Their hypothesis was that if unconditioned burying served a defensive function, approach-avoidance behavior, which occurs in response to both conditioned and unconditioned stimuli (Blanchard & Blanchard, 1970a, 1970b, 1971; Hudson, 1950), would occur in a high positive relation with it. Testing six hooded rats with a mousetrap, a flashbulb, and a

wooden dowel as potential aversive stimuli, they found that approach-avoidance responses and duration of burying occurred at high levels in the presence of the trap and the bulb but not in the presence of the dowel.

In an additional experiment, Pinel, Hoyer, and Terlecki (1980) demonstrated that both burying and approach-avoidance responding also occurred in response to a dowel soaked in cadaverine, a compound formed by bacterial action on decaying tissue. This was a follow-up on some work done by Pinel, Gorzalka, and Ladak (1981), who showed that rats will bury conspecifics which have been dead for 40 hours, but not those which have been dead for less than five hours.

If approach-avoidance behavior occurred only in the presence of aversive stimuli, it could be assumed that unconditioned burying serves a defensive function, but this is apparently not the case. Montoya, Sutherland, and Whishaw (1981) confirmed the results of Pinel, Hoyer, and Terlecki (1980), but went further and demonstrated that when rats were placed in a chamber with both plain Purina Rat Chow pellets and the same pellets soaked in cadaverine, they frequently preferred to eat, hoard, and bury the cadaverine soaked pellets. Since the rats did not avoid the cadaverine soaked pellets, it appears that not only is cadaverine nonaversive, but that all burying cannot be classified as defensive.

With further work in this area, Poling et al. (1981) showed that whether or not rats were food deprived, they buried Purina Rat Chow soaked in bitter tasting quinine, plain chow, and marbles, even though plain chow and marbles have no apparent aversive qualities. In addition, and in contrast to the results obtained with the mousetrap and flashbulb by Terlecki et al. (1979), burying marbles was not eliminated with repeated exposures.

It appears, therefore, that while conditioned burying

indeed serves a defensive function, unconditioned burying does not always do so. Furthermore, while habituation does not occur for all stimuli that are unconditionally buried, conditioned defensive burying (CDB) is attenuated in those instances in which habituation has occurred.

Drug Effects on Conditioned Defensive Burying

Just as the effects of various drugs on different types of learning are quite common, also common are experimental confounds related to learning versus performance. This is due to the fact that in many studies, both the associations or contingencies to be learned, as well as tests of performance, occur with the subjects in the drugged state. One advantage of the defensive burying paradigm is that the subjects can be conditioned while under the influence of the drug in question and tested later, in a drug-free state. Additionally, the behavior itself does not need to be taught (Beninger, MacLennan, & Pinel, 1980).

Beninger et al. (1980) demonstrated this in two experiments using pimozide, a neuroleptic drug which in low doses blocks dopamine receptors. First, pimozide was injected intraperitoneally prior to conditioning and testing and, in the second experiment, the injection was given only prior to conditioning. Rats in the drugged state during conditioning and testing engaged in less burying and less activity, in general, than did rats that were under the influence of the drug during conditioning only. Rats that were conditioned while under the influence of pimozide and tested while drug free displayed behaviors identical to those of rats that were drug free

at all times. These experiments demonstrate that while pimozide reduces conditioned responding, it does not significantly affect the learning processes involved.

In an experiment that compared the performance of rats conditioned and tested after an injection of insulin with insulin and saline-injected controls, Davis and Rossheim (1980) found that insulin-injected subjects buried shock prods and flashbulbs for shorter durations and with smaller accumulations of bedding material than did the control subjects.

A somewhat more involved experiment that examined the effects of drugs that affect catecholamine actions was carried out by Davis, Whiteside, Dickson, Thomas, and Heck (1981). Subjects were injected intraperitoneally with either Thorazine (a catecholamine antagonist), Elavil (a catecholamine potentiator), or saline one hour prior to conditioning and testing with a flashbulb stimulus. Twenty-four hours later, all of the subjects were retested for retention, with half of the subjects in each group in the drugged state and the other half drug-free.

During the original testing, the Elavil subjects spent more time burying the flashbulb than did the saline subjects, whose burying durations were greater than those of the Thorazine subjects. The piles of bedding accumulated by the Elavil and saline subjects did not differ, but both were greater than the Thorazine subjects' piles. During retention testing, no between-group differences were found, a result that is consistent with those of Beninger et al. (1980).

A more recent experiment was carried out by Whiteside and Devenport (1985), who examined the effects of naloxone and preshock on CDB. Other experiments have shown that the preshock administration of naloxone, an opiate antagonist, causes increases in postshock freezing (Fanselow & Bolles, 1979) and shock-elicited aggression

in rats (Fanselow, Sigmundi, & Bolles, 1980).

Whiteside and Devenport (1985) injected rats with naloxone or saline and subjected them to preshock or no preshock prior to giving them a CDB-eliciting test shock. The combination of naloxone and preshock led to the longest burying durations, regardless of whether the preshock was administered in the same setting or a different setting from the one in which the test was carried out. These results are consistent with the perceptual-defensive-recuperative model of defensive behavior proposed by Bolles and Fanselow (1980), which proposes that defensive behaviors are modulated, in part, by endogenous analgesics.

Although there are too few studies currently to be able to make any broad generalizations regarding the effects of drugs on CDB, those that have been carried out have demonstrated that when drug effects are manifested, they appear in the realm of performance rather than in the learning processes. The fact that the defensive burying paradigm lends itself so well to the separation of learning and performance variables suggests that CDB studies may become very important in the evaluation of newly developed psychotropic medications.

Durational Control of CDB

A large number of studies have been published since Pinel and Treit's (1978) seminal work in the area of CDB and researchers have attained a good understanding of many of the stimuli and conditions that control CDB, as well as conditions that differentiate it from unconditioned burying. Additionally, the work of Goldberg and his

colleagues, described later in this paper, (Goldberg & Cheney, 1981, 1982a; Goldberg, Ghezzi, & Cheney, 1983), Anderson, Nash, Weaver, & Davis, (1983), and Harder and Maggio (1983) has demonstrated amply that CDB persists across successive test sessions and that this persistence is a function of both the number of aversive stimulus applications in a single session and the number of sessions in which the stimulus has been applied. Thus, the accumulated research has clarified two of the conditions which increase CDB's persistence over time. To date, however, no research has attempted to determine the conditions under which any instance of the response is terminated.

There are two possible reasons for the termination of the CDB response. The first of these may simply be that just as the animal does not have to learn to bury, it does not have to "learn" to stop, that is, it simply does so because, as a part of its genetic makeup, brief changes in the functional properties of the stimulus do not lead to permanent changes in responding unless they are encountered repeatedly. In other words, response termination may have nothing to do with the effects of the response upon the eliciting stimulus.

The second possibility is that response-environment interactions control the burying response, in that, as the rat engages in CDB, the same sort of learning is occurring that occurs in other operants. This learning may then affect the CDB response, itself, as it occurs.

The first possible reason, that the rat does not "have to learn" to stop, is, in fact, the conclusion that could be drawn from the work of Treit, Pinel, and Terlecki (1980), in which the duration of CDB was a simple function of the magnitude of the shock, and of Anderson et al. (1983), in which the duration of CDB was a function of the number of shocks. The difficulty in interpreting these

studies accurately is that in both, only group means were presented for the heights of accumulated bedding material. Neither report states whether every animal covered the prod completely, although close examination of the figures presented in these papers makes it appear that they did not. In addition, Pinel and Treit (1982) have recently stated that the term "burying" is more descriptive of the behavior, itself, rather than of the consequences of the behavior.

In our own laboratory, on the other hand, each of the animals that engaged in CDB not only covered the prod in sessions in which shock was delivered, but continued burying even after the prod (or lever) had been covered completely. The only exception to this occurred very recently. In an attempt to make videotapes of rats engaging in CDB, a systematic replication of Experiment 2 was to be carried out in the experimental chamber to be used in Experiment 5. As Session 5, the first shock delivery session for each animal commenced, a 75 watt bulb was illuminated directly over each of the two oval shaped, hardware cloth covered holes in the top of the chamber, with the light directed down into the chamber. Despite the fact that the number of shock deliveries to each subject ranged as high as three, no subject engaged in even a full second of CDB.

The animals were then run with the lights on for 12 more sessions, and shocks were delivered in Session 19, with the lights still on. Brief durations of CDB were observed in some animals, but no animal covered the lever completely. Shocks were delivered again in Session 21, and five of the six rats engaged in some CDB. Only one covered the lever.

Following this, the rats were run for four sessions (#22-25) without the lights. In Session 22, one rat exhibited just under 6 seconds of CDB. Shocks were again

administered in Session 26, in the absence of the lights. Three of the six rats engaged in some burying, with durations ranging from only 5.8 to 17.3 seconds, and one animal (a different one) covered the lever completely (Goldberg, 1984).

Apparently, the sudden addition of such bright lights in close temporal proximity to the initial shock deliveries resulted in a severe enough alteration of the setting that the stimulus qualities of the lever alone were overshadowed by the light. This appears to be a perfect example of a situation in which "the behavior of the manipulator becomes part of the learning event" that Kantor (1970, p. 104) described.

Of particular interest was the fact that although the burying response, an SSDR, was almost completely inhibited, the learned lever press response was apparently unaffected. No reports of similar (i.e., non-pharmacological) disruptions of SSDRs have been found in the literature.

Summary

The data accumulated to date make it clear that CDB is an extremely robust phenomenon. Because it is elicited by an aversive stimulus, is functionally directed toward the stimulus object, and potentially protects the organism from future contact with it, CDB is a clearly defensive reaction. That the behavior is exhibited by some species but not others means that the list of SSDRs in rats proposed by Bolles (1970, 1971) must be modified. Still missing from the accumulated data, however, is any explanation of the variables controlling the termination

of the burying response.

One facet of particular interest is the rapidity with which acquisition and retention of discriminated CDB occurs; a single trial is sufficient. Pinel, Treit, and Wilkie (1980) suggest that this may be due to two factors operating concurrently. First, the burying behavior itself does not have to be shaped: once the organism has learned the change in stimulus function, it does not have to learn the biological act. Second, unlike many other forms of traditional classical conditioning, there exists spatial contiguity between the aversive stimulus and the stimulus object. This conclusion is supported by experiments carried out by Rescorla and Cunningham (1979), who demonstrated that second-order classical conditioning is facilitated by spatial contiguity of the two conditioned stimuli.

Spatial contiguity of stimuli is also probably a more accurate reflection of what occurs for organisms in the natural environment. Pinel, Treit, and Wilkie (1980) have stated,

Slower rates of learning in traditional conditioning experiments thus may result more from the artificial arrangements of stimuli in the standard test paradigms than from limitations in the rat's learning capacity (p. 162).

In the first half decade or so of experimentation on conditioned defensive burying, the typical procedure was to preexpose the rat (in most cases) to the test environment, apply an aversive stimulus, and measure the degree to which the rat used whatever substrata was available to bury the source of the aversive stimulus. Other than many of the conditions and parameters under which burying is elicited, very little is known about defensive burying as a complete response sequence. The known conditions and parameters include the types of

stimuli that elicit the behavior, various substrata the organisms employ during the response, and factors that weaken the response. Each of these, however, is a condition under which defensive burying is initiated and carried out. None explores the variables that maintain the response after its elicitation has occurred. It is the intent of this paper to attempt to determine these variables.

CHAPTER III

OBJECTIVES AND HYPOTHESES

Introduction

As stated previously, no research published to date has attempted to explore the variables that maintain CDB after its elicitation has occurred. The series of six experiments presented examine the interaction of the rat's burying response and the environmental changes resulting from that response, in an attempt to determine the variables that control the response's duration. The experiments were an attempt to determine the degree to which CDB is controlled by its functional consequences.

In order to better understand CDB, an almost "behavioral ecological" approach (Shettleworth, 1984) must be taken. Defensive burying is one of those instances of learning that has not yet been subjected to analytical scrutiny (Roper, 1983) and, because it is a directed respondent (i.e., one which involves movement toward a specific location), it is one of those behaviors for which a more "organic" (i.e., holistic) approach (Jenkins, 1973) is appropriate.

In studying phenomena such as CDB, the environment for the rat consists of the rat, itself, as well as the surroundings with which it interacts (Smith, 1985) and alters, physically, during the burying response. Therefore, rather than to approach the problem in terms of

a "sequential, operant analysis," the interactions between the rats and their environments are "described functionally, in terms of historically defined stimulus and response events" (Bijou, 1984, p. 534). This approach was taken because, "In order to understand the behaviors of organisms, it is necessary that they be studied as interactive processes, and not as isolated, unitary phenomena" (Goldberg et al., 1983).

Objectives

As stated above, severe limitations exist in the full understanding of CDB. Although much is known about the conditions necessary for its elicitation, very little is known about the entire process. As such, it must be observed repeatedly in its unaltered form, that is, over repeated trials. Prior to the experiments presented in this paper, none similar had been published. Therefore, a methodology had to be developed for studying the burying phenomenon under repeated trial conditions. In order to do this, it was first necessary to demonstrate that the standard one-trial technique for obtaining CDB could be replicated in our laboratory.

Objective 1

The first objective was to demonstrate that CDB could be obtained in our laboratory when the standard one-trial technique was employed. The first experiment simply was an attempt to accomplish this.

The next step was to develop a new methodology to study in depth the burying response, itself. This was

necessary in order to determine what, if anything, rats learn during the actual burying that occurs during CDB, as opposed to what they learn prior to burying. A method had to be found to control the stimulus functions of the shock source in such a way as to force the subjects to repeat a response which, on at least one occasion, has been punished; they had to recontact the prod after already having been shocked by it.

Objective 2

The second objective was to develop a method to force the subjects to recontact the source of the aversive stimulus in order to be able to determine what the rats learn while burying, as a function of repeated contacts with the aversive stimulus. This was attempted through the employment of a lever-press-for-water contingency when no other source of water was available.

Because the development of the appropriate methodology for further study was of prime importance, it had to be demonstrated that the methodology employed was reliable in eliciting CDB. Otherwise, it could be argued that failures by subjects to bury the sources of aversive stimulation might be due to faulty experimental methodology, rather than to variations in the independent variable.

Objective 3

The third objective was to demonstrate that the methodology employed throughout this series of experiments was sound. Thus, the third experiment was a systematic replication (Sidman, 1960) of the second one.

Once the second and third experiments had been completed successfully, that is, the rats had buried the lever, returned to it, received a second shock trial, and

buried it again, it had to be demonstrated that the burying that occurred was a function of the delivery of the aversive stimulus (shock), rather than the result of other aversive qualities that might be associated with any alteration of the stimulus functions of the lever.

Objective 4

The fourth objective was to verify that the burying obtained in the second and third experiments was, in fact, a function of the application of the aversive stimulus, that is, shock. The fourth experiment examined the effects of altering the stimulus functions of the lever in a less severe fashion. No shocks were delivered; the rats simply stopped receiving water for pressing the lever.

Given the groundwork laid in the first four experiments, the last two experiments attempted to determine the variables that control the duration of the burying response. The primary question to be answered was whether the duration of conditioned defensive burying is a function of its consequences.

In actuality, there were two parts to this question, because the burying of the source of an aversive stimulus typically serves two functions. The covering of the shock source has two results: the rats are protected from contact with the lever and they are unable to see it.

Objective 5

The fifth objective was to determine whether CDB is affected by its consequences. As such, the fifth experiment allowed only one group of subjects the opportunity to cover the lever completely, thus making the burying response dysfunctional for the other two groups.

Objective 6

The sixth objective was to determine whether CDB is affected by varying only one function of its results--the rats' ability to see the source of the aversive stimulus. The sixth experiment allowed the rats to cover the lever, however, only one group of rats was permitted to block the lever from view, completely.

Hypotheses

Due to the fact that defensive burying had been obtained in a great number of laboratories over past years, there was no reason to expect that it would not be obtained in ours. Even though our rats had prior experience with lever-pressing for water and everyone else's had been experimentally naive in all respects, it was expected that burying would be obtained in the first experiment.

Hypothesis 1

CDB could be obtained in our laboratory using the standard, one-trial methodology.

Hypothesis 2

The lever-press-for-water contingency would result in the subjects recontacting the lever even after they had received shock(s) through it.

Hypothesis 3

The second experiment could be replicated systematically in that, again, the subjects--now two different strains of laboratory rat--would recontact the

lever for water reinforcement even after being shocked through it.

Hypothesis 4

The burying obtained in previous experiments would not be obtained as the result of a change in the stimulus source that was not painful.

Hypothesis 5

No statistically significant differences between groups would be obtained as the result of allowing only one of three groups of rats the opportunity to bury the lever completely. This was because the stimuli that elicit CDB are unlike those that elicit other SSDRs. In rats, for example, fleeing, fighting, and freezing typically are elicited by predators which actively move about. As a result, freezing terminates as a function of time following the departure of the predator, or becomes fleeing or fighting if the rat is attacked. Fleeing terminates when the threat has been escaped or when the rat has been caught, and fighting terminates when the predator has been driven off, or the rat has been killed or incapacitated.

Although CDB, like the other SSDRs, is elicited by an aversive stimulus, the elicitor is passive and immobile. The elicitor does not pose the same active level of threat to the rat that is posed by predators, and the threat does not end in a discriminable fashion, such as when a predator departs. The termination of the burying response sometimes precedes, and, at other times, occurs well after the actual covering of the source of the aversive stimulus. Thus, it seemed unlikely that CDB is under the same type of consequential control that controls other SSDRs.

Hypothesis 6

No statistically significant differences between the groups' burying durations would be obtained as a function of the differences in the groups' opportunities to see the lever after it had been buried, as the result of the differences in the transparency of the available substratum.

The reasoning used in predicting the results of the fifth experiment also applied in this case.

The general hypothesis was that the duration of CDB is not a function of its consequences, for the reasons specified in the fifth hypothesis. This would mean that, like other SSDRs, CDB is not controlled by its consequences. Alternatively, if CDB termination is a function of its consequences, the fifth and sixth experiments, in combination, would determine whether CDB termination is a function of stimulus visibility or only stimulus covering, per se.

CHAPTER IV

EXPERIMENTS

Experiment 1

All but one of the burying experiments described to this point except those using classically conditioned stimuli and the report by Silverman (1978), who was not studying burying, per se, have one thing in common: each animal has received a single application of the unconditioned aversive stimulus followed by a single session to test for the burying response.

The lone exception to this was the Thorazine-Elavil experiment by Davis, Whiteside, Dickson, Thomas, and Heck (1981), in which a retention test was administered 24 hours after the original conditioning test. Because these investigators were examining the effects of drugs on the learning/performance distinctions involved in CDB, they failed to provide any report on the interactions of the animals with stimuli in an altered environment, that is, an environment in which an object, the flashbulb, had been the source of an aversive stimulus. The authors did not report whether the subjects' behavior toward the bulb changed as a result of the first flash trial.

An examination of the article's figures, however, indicates that each group spent less time burying the stimulus during the retention test than during the initial, conditioning test and that the accumulated piles

of bedding showed a similar decline.

The figures presented by these authors raise an obvious question: how does the rat behave over time as a part of the altered environment, that is, how persistent is the burying response after its initial elicitation? Experiment 1, the first of a series of investigations of repeated testing and repeated UCS applications carried out by Goldberg and his colleagues (Goldberg & Cheney, 1981, 1982a; Goldberg, Ghezzi, & Cheney, 1981, 1983), was run in order to make this determination, after establishing that CDB could, in fact, be obtained in their laboratory.

Method

Subjects. Three adult female albino rats (228-244 g) served as subjects. Three months prior to participating in this experiment, they had served as subjects in an introductory experimental psychology class. The laboratory exercises in which the rats participated included lever-press training on a continuous (CRF) schedule of water reinforcement, fixed-ratio responding (FR 20), extinction, and spontaneous recovery.

Apparatus. The apparatus used in this experiment was identical to the ones used in the psychology class, except for the modification of the operandum and the addition of wood shavings within the chamber. It was a 23 x 20 x 19 cm Scientific Prototype Rodent Test Cage (A110) with a liquid dispenser. The floor was of steel grid construction with a tray underneath. This tray was filled completely with wood shavings to a depth such that when the shavings were spread evenly throughout the chamber, they were 4.5 cm above the grid surface. The side walls and ceiling of the chamber were constructed of clear Plexiglas and the front and rear walls were aluminum. In the center of the front wall, 4.5 cm from the floor, a metal lever, 5.1 x 1.3 cm (W x H), extended 1.9 cm into

the chamber. The lever was covered with black electrical tape and over the tape were wrapped two parallel uninsulated wires. These wires were attached to a BRS/LVE SG-903 shock generator with the shock intensity set at 10 mA. To the left of the lever, extending 3.8 cm into the chamber, was a drinking spout, 1.3 cm in diameter. The reservoir at the end of the spout was 1.4 cm above the chamber floor. The liquid dispenser was inoperable throughout this experiment.

Procedure. The three rats were housed individually with food and water available continuously. Each rat was individually preexposed to the chamber for 30 minutes at the same time each day for three consecutive days. On Day 4, the shock was turned on by the experimenter the first time each rat touched the lever with a forepaw, and was terminated by the subject's withdrawal from the lever. Burying duration (i.e., the amount of time the animal spent moving wood shavings toward and over the lever with snout and forepaws (cf. Peacock & Wong, 1982), was recorded with an electrical timer for the succeeding 15 minutes, after which the rat was returned to its home cage. The subjects were also observed for 15 minutes (no shock) and burying durations recorded on Days 5, 6, and 11 through 13. Each session began with the wood shavings pushed to the rear half of the chamber, in order to keep the layout of the experimental environment constant across animals and sessions.

Results and Discussion

Although some burrowing and moving of the wood shavings were observed, no burying occurred prior to shock delivery. All three rats buried the lever completely on Day 4, with durations of burying ranging from 97 seconds to 121 seconds (see Figure 1). Each rat also engaged in a much smaller amount of burying on Day 5 and none on Day 6.

Upon being returned to the chamber on Day 11, one rat engaged in a very brief (1.7 seconds) period of burying. No burying was observed by any animal on Days 12 and 13. None of the rats recontacted the lever following shock delivery.

It is clear from the data that rats with an extensive history of water-reinforced interaction with the lever will bury a similar lever in the same setting following a single shock delivered through it, and that the behavior recurs thereafter for a session or two beyond the shock session. Thus, a single, brief change in the function of the stimulus leads to a much longer alteration of behavior, as demonstrated by the repetition of the behavior beyond the session in which shock was delivered.

Additionally, despite the frequent findings that CDB is attenuated by prior exposure to the test environment (e.g., Oberdieck & Tarte, 1981; Tarte & Oberdieck, 1982), the substantial amounts of burying that occurred suggest that this attenuation is either an asymptotic or bitonic function of time. It is also possible that the burying durations would have been greater if the rats had had less prior exposure to the experimental environment.

The first hypothesis is retained.

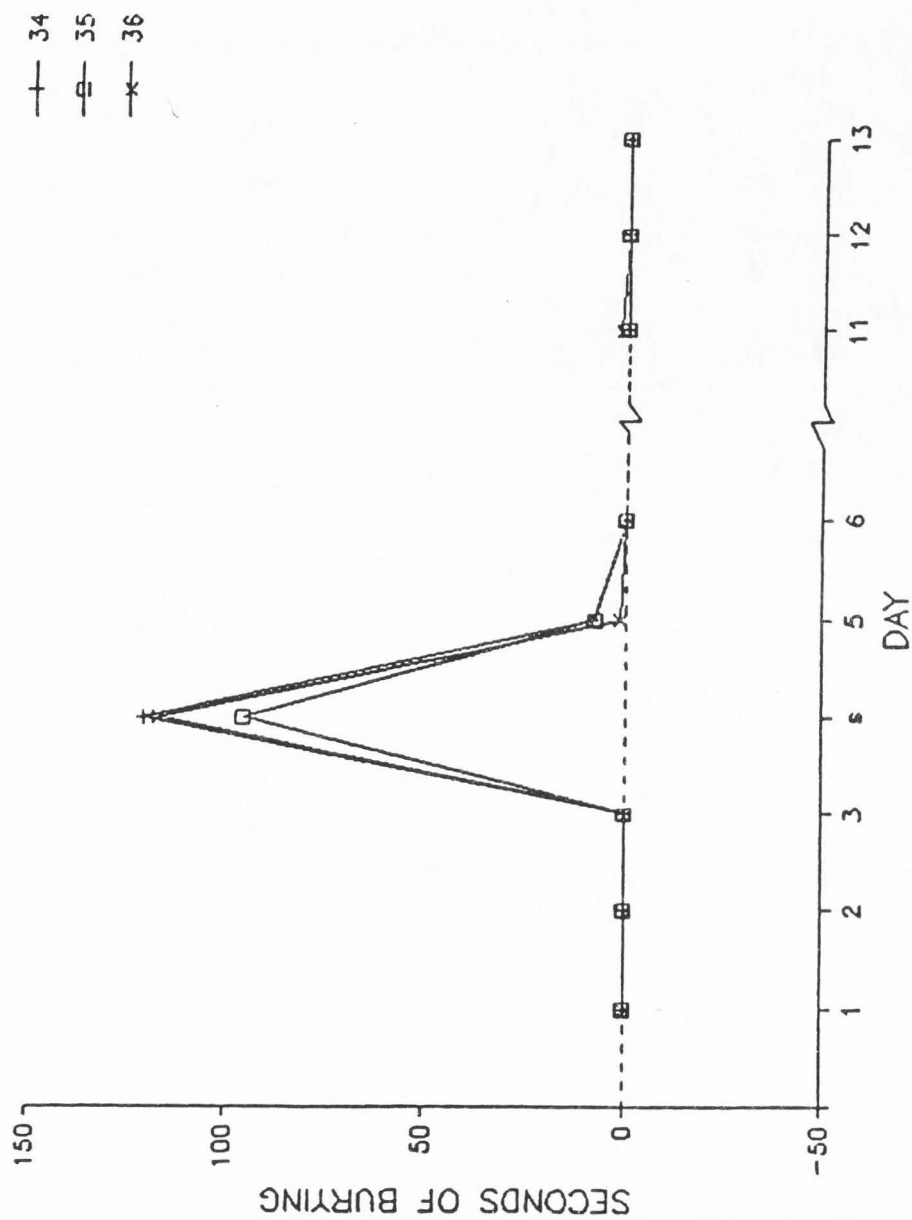


Figure 1. Experiment 1: Time spent burying across days.
Shock was administered on Day 4.

Experiment 2

Experiment 1 demonstrated that rats with histories of preexposure far exceeding those in any other study will not only engage in CDB, but that the response persists beyond the initial conditioning session in spite of this. A brief period of spontaneous recovery was even observed in one animal.

The next question to be answered was this: what will be the effect on the persistence of CDB over the course of repeated alterations in the stimulus function of the lever? In order to answer this question, a method had to be found that would ensure that every subject would recontact the lever. The technique employed was to make such contact necessary for the animals' survival. In this case, contingencies were arranged such that the rats could obtain no water without pressing the wire-wrapped lever (Goldberg & Cheney, 1981; Goldberg et al., 1983).

Method

Subjects. Three adult female albino rats, with histories and weights similar to those used in Experiment 1, served as subjects.

Apparatus. The chamber used in the first experiment was used again. The only alteration was that each depression of the lever was followed immediately by the delivery of 0.2 cc of water, which was accompanied by an audible click.

Procedure. The three subjects were housed individually with lab chow available continuously. For four days, access to water was limited to five minutes per day in the home cages. It was then discontinued. Each daily session began with the wood shavings pushed to the rear half of the chamber. In Session 1, each animal that

did not press the lever within the first five minutes was shaped by successive approximations to press the lever. Each rat was left in the chamber for one hour and the CRF schedule of water reinforcement was in effect throughout the experiment. During Sessions 2 and 3, each rat was allowed 30 minutes of reinforced lever pressing. All future sessions except those in which shocks were delivered were limited to 15 minutes.

Sessions 6 and 14 were identical to the others except that as each rat pressed the lever for the sixth time (arbitrarily chosen), the experimenter turned on the shock, which was terminated by the withdrawal of the subject. If the animal pressed the lever again within 5 minutes, before burying it, shock delivery was repeated. During the 15 minutes following the last shock delivery, the duration of burying behavior was recorded on an electric timer. Each rat was removed from the chamber 15 minutes after the last shock.

Results and Discussion

No burying was observed by any subject prior to the first shock. Unlike all previous studies of CDB, a single shock was insufficient to elicit long burying durations, although one rat exhibited a brief (1.1 seconds) period of burying before returning to the lever and receiving a second shock. In each subject, the first shock elicited an immediate withdrawal from the lever which was accompanied by a vocalization. Following this was a brief period of approach-avoidance behavior that preceded the next contact with the lever.

After the second shock, no subject pressed the lever again during Session 6 and each engaged in a substantial amount of burying of the lever (See Figure 2). While burying the lever, Subject 108 depressed the lever while packing shavings over it. Also while burying the lever,

each subject on at least one occasion accumulated shavings to at least 2 1/2 times the height of the lever, which resulted in shavings being spread at a substantial height across the entire front end of the chamber. The height of the shavings could not be employed as a valid dependent measure in this study, due to the unexpected stereotyped responding which each of the subjects exhibited. Peacock and Wong (1982) have questioned the validity of height measurements, in any case.

Following the initial complete burying of the lever, each rat returned to the area over and in front of the drinking spout and dug down through the shavings until the spout was entirely uncovered. The spout was then sniffed, frequently licked, and more shavings were then directed toward the lever. These tended to avalanche back over the spout, covering it again. This process was repeated two to four times by each of the subjects.

Upon being placed in the chamber for Session 7, each subject first buried the lever, with falling shavings covering the spout, and after repeating the sequence described above, eventually cleared the shavings and began pressing the lever and drinking from the spout again. During Session 8, a brief period of burying was exhibited by each subject, but responding returned to preshock levels, where it remained through Session 13 (See Figure 2).

The subjects' behavior during the next shock session, Session 14, was identical to that in Session 6, except that Subject 108 completely buried the lever after the first shock. The resultant effect was that Subjects 106 and 107, having received two shocks, engaged in at least a little burying through Session 19, when their lever pressing returned to preshock levels, while Subject 108

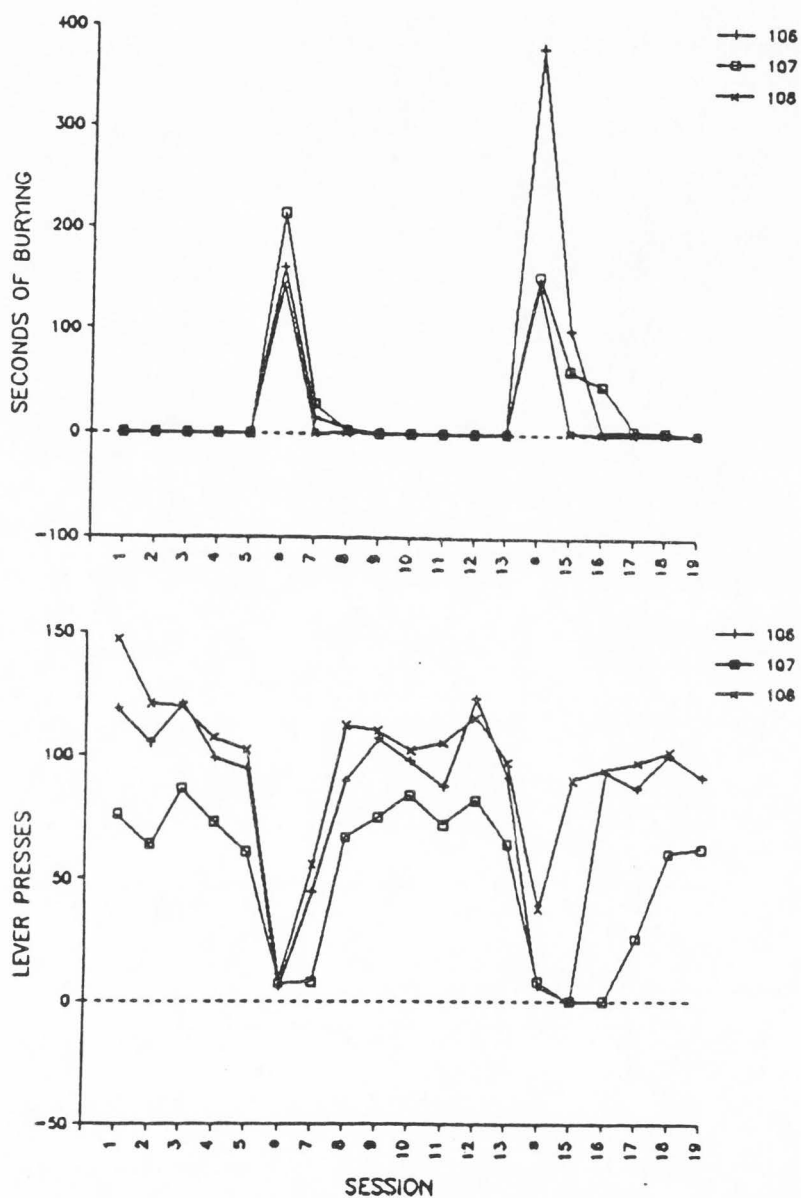


Figure 2. Experiment 2: Time spent burying and numbers of lever presses across sessions. Shocks were administered in Sessions 6 and 14.

ceased burying after Session 15 and was terminated from the study one session earlier than were the other two.

Two observations from this experiment merit attention. The first is that during the time that the rats were burying the lever, they exhibited a clear discrimination between the altered function of the lever, the shock source, and the unaltered function of the spout, the source of water. This is clear because each rat attempted to drink from the spout at least one session prior to its return to pressing the lever, a stimulus that had gained a second, aversive function. Second, the initial, single shock was insufficient to elicit burying. A second punished contact was required to establish a more permanent change in the rats' behavior. This is similar to results obtained in studies of taste aversion, in which aversions to a familiar CS are established with more difficulty and are relatively transitory, when compared to the establishment of aversions to novel stimuli (e.g., Cheney & Eldred, 1980; Garcia et al., 1977).

In relation to the persistence of CDB, Figure 2 shows clearly that the second set of shock deliveries did indeed increase the number of sessions in which Subjects 106 and 107 engaged in burying. Subject 108, which received only a single shock in Session 14, engaged in burying durations similar to those elicited by the first set of shocks. An evaluation of these data, limited as they are, suggests that holding the magnitude and frequency of subsequent shock deliveries constant tends to increase changes in the psychological field that have been established through previous interactions between the rat and the lever; thus, the increase in the persistence of CDB. Furthermore, a decrease in subsequent shock deliveries appears to maintain the changes in the rats' interactions with the shock source in their environment, as opposed to allowing them to return to their previous state, as was in

process at the end of Experiment 1. Hence, CDB persistence remains constant.

The second hypothesis is retained.

Experiment 3

Although the results of Experiment 2 are quite clear, the possibility exists that some of the conclusions drawn from them might be tenuous, at best, due to the limited number of subjects involved. Experiment 3, for all practical purposes a direct replication of Experiment 2, was run in order to ensure that the methodology for more complex, future studies was reliable. The only difference was that both hooded and albino rats were employed in this instance (Goldberg & Cheney, 1982a).

Method

Subjects. Six rats, four males and two females, were used in this experiment. Three were albinos and three were hooded. Their weights and histories were similar to those used in the previous experiments.

Apparatus. The apparatus was the same one used in Experiment 2.

Procedure. The procedure was unchanged from the previous experiment.

Results and Discussion

The results obtained in this experiment were almost identical to those obtained in Experiment 2. The only differences were that all six rats received two shocks in Session 14 and that both burying durations and responses per session were not as high as those obtained previously

(See Figure 3 and note the differences between Figures 2 and 3). This was especially noticeable in the burying durations of the hooded subjects, in which the longest duration was barely one-half of the shortest duration exhibited by any albino. Also consistent with the previous experiment was that the persistence of burying increased following the second set of shocks.

It appears quite clear, therefore, that the conclusions drawn from Experiment 2 are correct: the changes in the rats' behavior toward the lever are maintained in the absence of changes in the magnitude and frequency of shock deliveries. This is demonstrated by the increase in the persistence of the burying response across shock trials in this experiment. Also noteworthy is the fact that all of the subjects in Experiments 2 and 3 buried the lever, their only access to water, while in a state of extreme water deprivation, a condition that has been demonstrated to attenuate the burying response (Davis, Hazelrigg, Moore, & Petty-Zirnstein, 1981).

In both Experiments 2 and 3, there was an increase in the amount of time taken by the rats to return to lever pressing across shock trials. This suggests that with enough repetitions of shock, the subjects could cease to discriminate the dual functions of the lever as water source and as shock source. The lever as shock source could then overshadow completely the lever as water source. As a result, the animals could die of dehydration. This hypothesis was not tested.

The third hypothesis is retained.

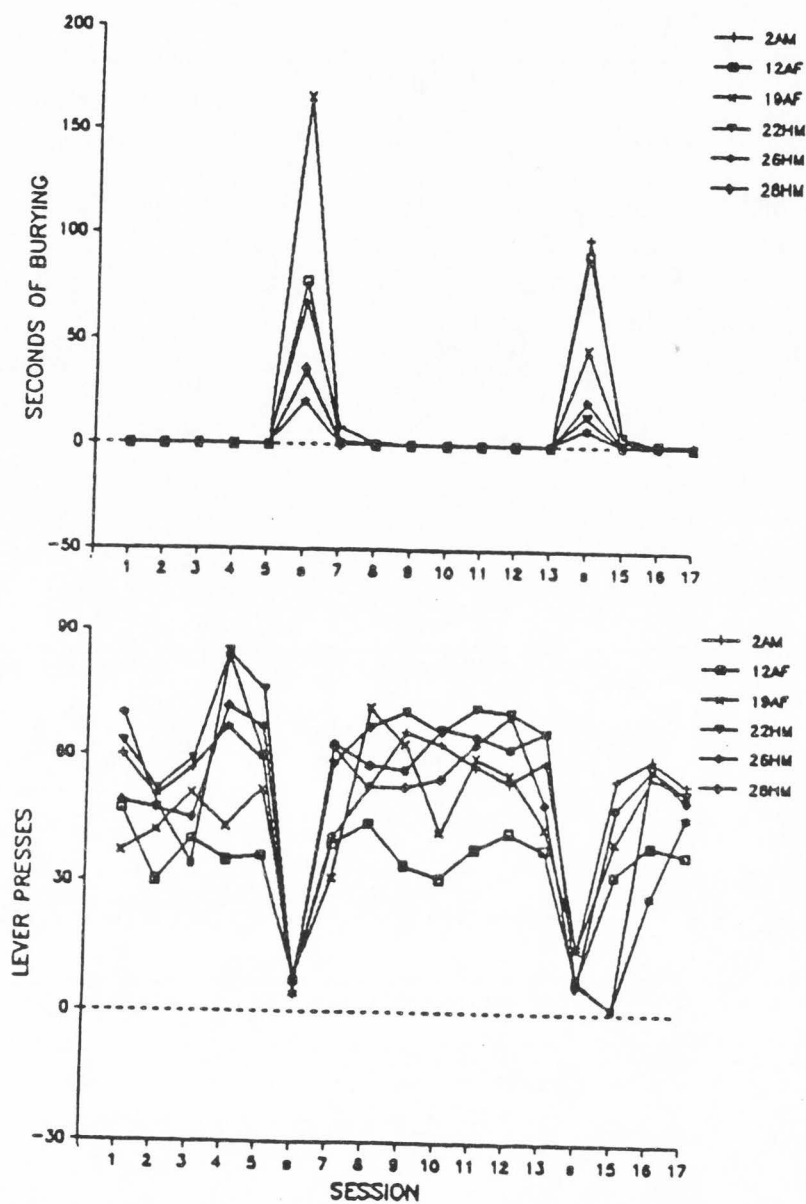


Figure 3. Experiment 3: Time spent burying and numbers of lever presses across sessions. Shocks were administered in Sessions 6 and 14.

Experiment 4

The results of the previous three experiments demonstrate that a stimulus either previously or currently functioning as an access to water will be buried over successive sessions after functioning as a shock source. The purpose of Experiment 4 was to determine whether this burying was, in fact, a function of the shock deliveries, rather than being a result of any change in the lever's function away from an exclusive association with reinforcement. The change was made by eliminating the water function of the lever (operant extinction). Operant extinction is known to have aversive properties (Azrin, Hutchinson, & Hake, 1966). This would permit a determination of whether a nonshock aversive event was a sufficient condition to elicit CDB (Goldberg et al., 1981, 1983).

Method

Subjects. Three adult female albino rats (248-274 g), with similar histories to those used previously, served in this experiment.

Apparatus. The chamber was identical to the chamber used in the three previous experiments, except the lever was not covered by tape or wire.

Procedure. The rats were housed individually with food available continuously. When each animal was pressing the lever consistently (two to three sessions), supplemental water in the home cage was discontinued. Each rat then received eight 30-minute sessions of continuously reinforced (CRF) lever pressing prior to at least three 30-minute sessions of extinction. Sessions were discontinued when the rats' body weights fell below 78% of free consumption.

Results and Discussion

Each rat quickly learned to respond for all of its water needs during the CRF sessions. As expected, responding decreased during extinction (See Figure 4), but none of the animals exhibited any burying behavior. In this context, the omission of lever pressing by the rats is biologically functional because it conserves the strength of the organism. Previous research has demonstrated that stimuli associated with operant extinction acquire aversive properties (e.g., Azrin et al., 1966). Although extinction may be aversive, it was insufficient to elicit burying in this experiment. Similar results were reported by Kelley (1985), who studied thigmotaxis (a tendency of animals to orient toward vertical surfaces or objects and to avoid open spaces) in rats. Thigmotaxis increased following mild shock deliveries but was unaffected by the frustration of nonreward.

The fourth hypothesis is retained.

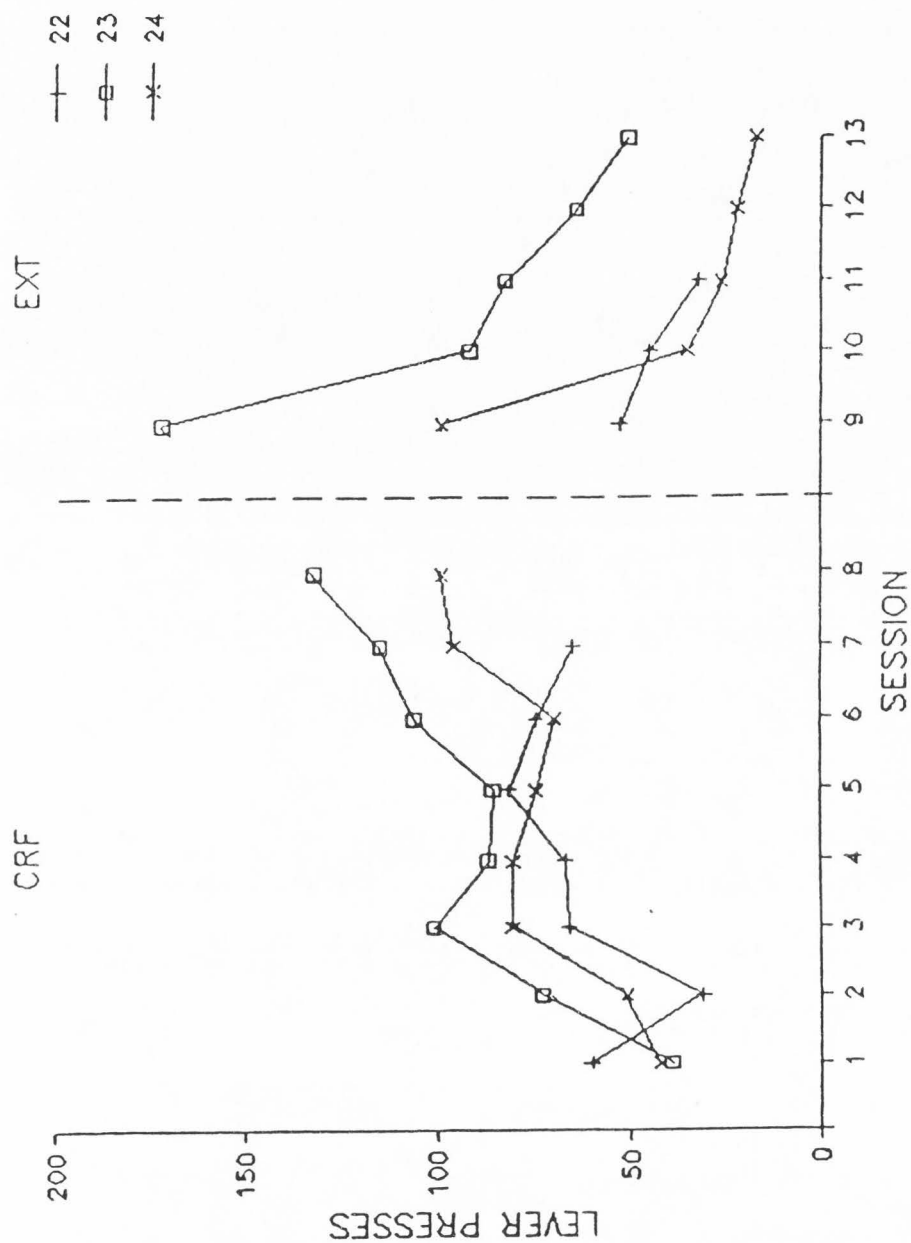


Figure 4. Experiment 4: Numbers of lever presses during continuous reinforcement and extinction.

Discussion: Experiments 1-4

Experiments 1, 2, and 3 support previous demonstrations that rats bury sources of aversive stimulation (e.g., Pinel & Treit, 1978, 1979) and that they are able to form an immediate discrimination regarding the source (Pinel, Treit, & Wilkie, 1980). More important, however, is the clarification of the effects of prior exposure to the test setting and the functional history of the shock source. Although preexposure has been demonstrated to attenuate CDB (Oberdieck & Tarte, 1981; Tarte & Oberdieck, 1982), the first three experiments indicate clearly that burying is not precluded by an extended history of preexposure to the setting and/or the stimulus.

The results of Experiments 2 and 3, in which burying occurred only after the delivery of a second shock, are similar to results obtained in studies of taste aversion acquisition with familiar flavors. In both the present studies and in studies with such varied species as wolves (Garcia et al., 1977) and opossums (Cheney & Eldred, 1980), a single exposure to the aversive function of the stimulus was insufficient to effectively alter the hedonic value (Garcia et al., 1977) of familiar stimuli, that is, to alter the behavior directed toward the stimulus.

The effectiveness of a single shock in eliciting CDB in Experiment 1 and not in Experiments 2 and 3 may have been due to a positive shift in the hedonic value of the lever caused by the water deprivation/lever-press contingency imposed in the second and third experiments. When a stimulus' functions are life supporting, as opposed to neutral in this respect, repeated changes of its function are necessary in order to change the organism's behavior, regardless of whether the behavior change is adaptive.

Davis, Hazelrigg, Moore, and Petty-Zirnstein (1981) reported that water deprivation attenuates CDB, and others (e.g., Tarte & Oberdieck, 1982) have reported that long periods of preexposure do the same. These variables, however, must be viewed as individual/interactional variables within the total environment. Otherwise, CDB would not have occurred in this experiment.

The finding that burying did not occur when the lever stopped serving as an access to water in the fourth experiment suggests that the functional qualities of such a change are clearly different than those of shock, flashbulbs, airblasts, and other stimuli which have been demonstrated to elicit CDB. Although the change from CRF to extinction appears to be a sudden and clearly discriminable aversive event, it is apparently insufficient to elicit CDB. This may be due to the fact that, like the "moldy food pellet" described by Parker and Smith (1981), the lever does not pose a direct physical threat to the rat during extinction.

Overall, it appears that even though CDB can be pushed to the point that it becomes dysfunctional physiologically, this is likely to occur only within artificial environments that can be created in the laboratory. From a purely ecological/naturalistic viewpoint, CDB is very functional in that it occurs only after a discrete object has become clearly aversive in its function.

Since these experiments were completed, studies employing multiple trial procedures have been carried out in other laboratories, as well. Anderson et al. (1983) compared the effects of a single shock with those of multiple shocks, with no other contingencies in effect. Following preexposure, rats in two groups ($n=8$) each received a shock upon first contacting a wire-wrapped, wooden prod. During the next 15 minutes, in which burying

durations were recorded, rats in the multiple shock group received an additional shock each time they recontacted the prod (Mean no. of shocks=2.37; SD=.70). The rats were returned to the chamber for 15-minute periods of testing, without further shocks, 24 and 48 hours later.

The results of this experiment were that rats in the multiple shock group exhibited longer burying durations than the single shock controls in each of the first two sessions, but not in the third. Furthermore, all of the animals buried more in Session 1 than in Sessions 2 and 3, and more in Session 2 than in Session 3.

The finding that, "By the second day of extinction (Test Session 3) animals in both groups devoted only a small portion of the test session to defensive burying" (Anderson et al., 1983, p. 189), is nearly identical to the results described above from our own laboratory. The amount of burying decreases rapidly across test sessions, regardless of the presence of a lever-press contingency, but some persistence of burying was still evident in all cases. Less clear is why the rats in the Anderson et al. (1983) study recontacted the lever and, in fact, it is possible that not all of them did so. Similar results have been obtained in a single-shock, two-test experiment employing mice as subjects (Harder & Maggio, 1983).

Experiment 5

In an attempt to determine if termination of CDB is a function of its consequences, three groups of rats, working under the lever-press-for-water contingency, were shocked through the response lever. For all three groups, the chamber's substratum consisted of sawdust. For one

group, sawdust was provided in sufficient quantity to allow the occurrence of the burying response, but there was not enough sawdust for lever covering to occur. For the other two groups, sawdust was provided in sufficient quantity to allow covering of the lever. For one of these groups, however, a hole was opened below the lever in such a way that the sawdust drained out, preventing the lever from being hidden, although some sawdust could remain on top of it.

Method

Subjects. Twenty-four Sprague-Dawley albino male rats, 61 days old on the first day of training, served as subjects. They were randomly divided into three groups of eight.

Apparatus. The experiment was conducted in a chamber which measures 43.2 x 43.8 x 30.5 cm and which opens at the top for placement and removal of the rats. The front, rear, top, bottom, and right side of the chamber were made of plywood, the inside of which was colored flat black with liquid plastic (Varathane, The Flecto Company, Inc., Oakland, CA). The left side was made of clear (uncolored), transparent Plexiglas. The top had two oval shaped, hardware cloth covered holes, each measuring 22 x 14 cm.

The rectangular response lever was made of clear, translucent Plexiglas and was wrapped with two uninsulated wires. These were connected outside the chamber to a BRS/LVE SG-903 shock generator, which was set at 10 mA. The lever measured 4.4 cm wide, 1.3 cm high, and protruded 1.9 cm into the chamber through the front wall. The left edge of the lever was 12.1 cm from the left (Plexiglas) wall of the chamber and its bottom was 7.6 cm from the chamber floor. Also protruding through the front wall was the 1.3 cm diameter drinking spout of a Scientific

Prototype Liquid Dispenser. It was 6.7 cm from the chamber's right wall and 6.4 cm from the floor.

Directly below the lever was a removable, trapezoidal section of floor which measured 9.5 cm along the front wall and 7.6 cm along its front edge, which was 3.5 cm from the front wall. Covering the hole that was left by the removal of this floor section was a single layer of hardware cloth which had been cut such that the open squares were approximately 2.5 cm across.

Electromechanical equipment located just outside the chamber was connected in such a way that each press of the lever resulted in the delivery of 0.2 cc of water, which was accompanied by an audible click.

The floor of the chamber was covered to a depth of 6.0 cm with sawdust for two of the groups. For one of these two, the hole below the lever was opened during burying. For the third group, a raised floor was inserted and covered with approximately 0.3 cm of sawdust. In this way, the bottom of the lever was 1.6 cm above the level of the sawdust for each of the groups.

Procedure. The rats were housed individually with food available continuously. On the day prior to the first day of training, water bottles were removed from their cages. On the next day, lever press training began, employing reinforcement of successive approximations to lever pressing. Following each of the four days of training, each rat received between five minutes and 15 minutes of access to water in the home cages, as seemed a necessary supplement. Following the last day of training, when all the rats had learned to press the lever for their water needs, water in the home cages was made available for 30 minutes. Following this, water in the cages was discontinued, and daily, 15-minute chamber sessions were commenced. All sessions began with the sawdust spread evenly throughout the chamber. All sessions except those

in which the rats were shocked (Sessions 6 and 14) lasted for 15 minutes. Sessions 6 and 14 began with the water spout full (approximately 1 cc). The spout was also full for any rat that had made fewer than 11 lever presses during its previous day's session. Otherwise, all sessions began with the water spout empty.

Sessions 6 and 14 were identical to the others except that as each rat pressed the lever for the sixth time (chosen to match the previous experiments), a shock was delivered through the lever, which was terminated by the animal's withdrawal. If any rat pressed the lever again before 15 minutes had passed, shock delivery was repeated. No animal received more than 2 shocks. These sessions were continued for 15 minutes following the last shock.

During each session, an electromechanical counter monitored the number of lever presses. The amount of time that each rat engaged in CDB was measured using an electronic timer, which was activated by the experimenter.

All of the rats were treated identically throughout the experiment, except for the different substratum conditions for each group. Group SS experienced the raised floor and the small amount of sawdust, Group LS experienced the standard floor and a large amount of sawdust, and Group LSH experienced the same conditions as Group LS, except that the hole below the lever was opened when burying began. In some instances, the sawdust did not fall through the hole after it was opened, so the experimenter caused this to happen with his finger, by poking up, through the bottom of the chamber. Additionally, the hole was open at the start of each rat's session succeeding one in which that rat had engaged in burying behavior without returning to lever pressing (i.e., ten successive responses without engaging in any burying behavior). The experimenter closed the hole during sessions that started with it open when a rat

returned to lever pressing. Each session began with the sawdust spread evenly throughout the chamber (except directly over the open hole).

Results and Discussion

All rats learned to press the lever for their water needs. No burying of the lever occurred prior to the first shock delivery. As in the previous experiments employing the lever-press-for-water contingency, a single shock was not sufficient to elicit burying (for all but one rat in group LSH), and multiple shocks were necessary. Unlike previous experiments, not all the rats buried the lever completely in Session 6, although only one rat (Group SS) failed to exhibit any CDB. This lack of lever covering was due, at least partially, to the layout of the chamber.

All of the rats that exhibited CDB followed the same pattern: they used the right, front corner of the chamber, which was the chamber's darkest spot and the location of the spout, as a sort of home base. In some cases, they did all of their burying from this location. In others, they started the burying response near the back of the chamber but, rather than push the sawdust directly at the prod, pushed it first towards the right side wall (i.e., away from the left, Plexiglas wall, through which light entered the chamber), then along the right wall toward the front of the chamber, and, finally, turned left and pushed it towards the prod. Between bursts of burying, the rats stayed in the right front corner of the chamber, the "home base" area.

As a result of the unique pattern of burying and the favored location when not burying, the accumulated piles of sawdust near the lever and the resultant lack of sawdust in front of the spout enabled many of the rats that did not cover the lever to block the lever from their

views. That is, the pile of sawdust between themselves and the lever was higher than the tops of their heads. In order to view the lever, they had to climb the intervening pile of sawdust. This was true for six rats in Group LS, one in Group LSH, and none in Group SS. Very few of the rats covered the lever completely.

A one-way analysis of variance of the three groups' mean burying durations during Session 6 was carried out (see Table 2). The mean burying durations (in seconds) for each group during Session 6 were as follows: Group LS, 39.09; Group LSH, 34.73; Group SS, 24.26. The difference among these means was not statistically significant. η^2 was 0.03, indicating that only 3% of the variance in burying durations was associated with group membership.

Table 2

Experiment 5: Analysis of Variance Table for Session 6
Burying Durations

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio	Probability
Among Grps	2	928.74	464.37	0.29	0.75
Within Grps	21	33601.04	1600.05		
Total	23	34529.78			

Effect sizes, in the form of standardized mean differences (SMDs) were calculated by dividing the difference between the groups' means taken two at a time by the standard deviation for the groups' pooled scores, that is, $(M_A - M_B) / SD(A+B)$ (Cohen, 1977). Using Cohen's criteria, the SMD was very small for the LS-LSH comparison, small for the LSH-SS comparison, and medium for the LS-SS comparison (see Table 3). Overall, then,

the differences in the groups' mean burying durations during Session 6 ranged from very small to medium in effect size and were not significant, statistically.

Table 3

Experiment 5: Between-Group Effect Sizes for Session 6 Burying Durations

GROUPS COMPARED	LS-LSH	LSH-SS	LS-SS
Mean A	39.09	34.73	39.09
Mean B	34.73	24.26	24.26
SD(A+B)	43.77	37.99	30.47
SMD	0.10	0.28	0.49

During Session 7, some burying occurred, but most rats returned to pressing the lever, as well. No burying occurred in Session 8, and by the ninth session, response rates had returned to pre-shock levels.

The rats' behavior in Session 14, the next shock session, was similar to that in Session 6, except that fewer rats received two shocks prior to engaging in CDB (LS-5, LSH-5, SS-3), and larger differences in group mean burying durations were obtained. As in Session 6, all rats in Groups LS and LSH engaged in burying, but only 5 rats in Group SS buried, in contrast to 7 in the previous shock session. The groups' mean burying durations and numbers of lever presses in all sessions are presented graphically in Figure 5.

A one-way analysis of variance of the three groups' burying durations during Session 14 was carried out (see Table 4). The mean burying durations (in seconds) for each group during Session 14 were as follows: Group LS, 92.49; Group LSH, 41.29; Group SS, 3.14. These differences were statistically significant. The correlation ratio, η^2 , was 0.52. Therefore, 52% of the variation in the data can be attributed to group membership.

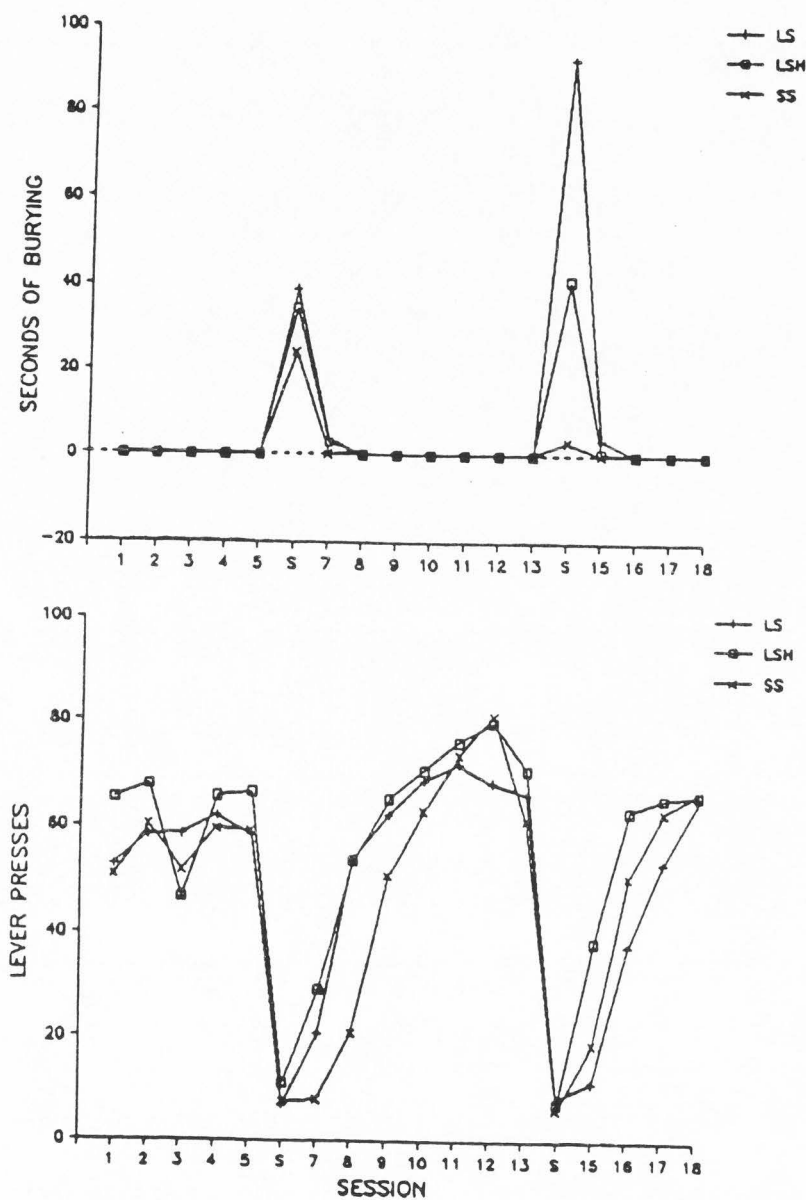


Figure 5. Experiment 5: Group mean burying durations and numbers of lever presses across sessions. Shocks were administered in Sessions 6 and 14.

Table 4

Experiment 5: Analysis of Variance Table for Session 14
Burying Durations

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio	Probability
Among Grps	2	32160.76	16080.38	11.35	0.00
Within Grps	21	29765.26	1417.39		
Total	23	61926.02			

Because the analysis of variance resulted in statistical significance between groups, Newman-Keuls multiple comparisons were calculated. The multiple comparisons resulted in statistical significance for the LS-LSH and LS-SS comparisons, but not for the LSH-SS comparison (see Table 5).

Effect sizes, in the form of standardized mean differences, were calculated (Cohen, 1977). These are shown in Table 6. According to Cohen's criteria, each is large. In summary, the differences in group mean burying durations in Session 14 were large and were unlikely to have occurred by chance, under the null hypothesis, given the sample size.

Table 5

Experiment 5: Results of Multiple Comparisons of Session 14 Group Mean Burying Durations

Multiple Comparison Results

Group SS	Mean: 3.14			
Versus	Mean	Difference	Nmn-Kls	
Group LSH	41.29	38.15	NS	
Group LS	92.49	89.35	Sign.	
Group LSH	Mean: 41.29			
Versus	Mean	Difference	Nmn-Kls	
Group SS	3.14	38.15	NS	
Group LS	92.49	51.20	Sign.	
Group LS	Mean: 92.49			
Versus	Mean	Difference	Nmn-Kls	
Group SS	3.14	89.35	Sign.	
Group LSH	41.29	51.20	Sign.	

Table 6

Experiment 5: Between-Group Effect Sizes for Session 14 Burying Durations

GROUPS COMPARED	LS-LSH	LSH-SS	LS-SS
Mean A	92.49	41.29	92.49
Mean B	41.29	3.14	3.14
SD(A+B)	50.08	28.39	58.49
SMD	1.02	1.34	1.53

In order to compare the three groups' burying durations across both shock sessions, a two-way analysis of variance (Groups X Shock Session) was carried out. Statistical significance was obtained for differences between groups and for the interaction between groups and shock session (see Table 7). Eta^2 s of 0.22 and 0.12 indicated that 22% and 12% of the variances were associated with group membership and the group-by-session

interaction, respectively. The Newman-Keuls method was used to make multiple comparisons. They yielded statistically significant differences between Group LS and Groups LSH and SS, but not between Group LSH and Group SS (see Table 8).

Table 7

Experiment 5: Two-way (Groups X Shock Session) Analysis of Variance Table for Burying Durations

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio	Probability
Btwn Groups	2	21737.06	10868.53	7.20	0.00
Btwn Sessions	1	2011.14	2011.14	1.33	0.25
Interaction	2	11352.43	5676.22	3.76	0.03
Error	42	63366.30	1508.72		
Total	47	98466.93	2095.04		

To assist in the examination of the statistically significant interaction obtained in the two-way analysis of variance, the observed cell means and the cell means that would be expected under the assumption of zero interaction are shown in Table 9. Each of the expected cell means was calculated by adding the overall mean for its row (Groups) to the overall mean for its column (Session) and subtracting the grand mean from that sum (Ferguson, 1981, p. 257).

The mean burying durations of Group LSH differed very little from what would be expected under zero interaction (Table 9, lower panel). The statistically significant interaction resulted from the mean burying durations of Groups LS and SS, which differed markedly from those that were expected.

Table 8

Experiment 5: Post-hoc Analyses of Two-Way Analysis of Variance

Multiple Comparison Results

Group SS Mean: 13.70			
Versus	Mean	Difference	Nmn-Kls
Group LSH	38.01	24.31	NS
Group LS	65.79	52.09	Sign.
Group LSH Mean: 38.01			
Versus	Mean	Difference	Nmn-Kls
Group SS	13.70	24.31	NS
Group LS	65.79	27.78	Sign.
Group LS Mean: 65.79			
Versus	Mean	Difference	Nmn-Kls
Group SS	13.70	52.09	Sign.
Group LSH	38.01	27.78	Sign.

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SMDs were calculated for each group, comparing the mean burying durations in Session 6 with those of Session 14. The respective standard deviations, pooled for Sessions 6 and 14, and SMDs for each group are as follows: Group LS, SD=53.06, SMD=1.01; Group LSH, SD=40.89, SMD=0.16; and Group SS, SD=17.55, SMD=-1.20. The differences for Groups LS and SS are large, according to Cohen's (1977) examples.

Overall, an examination of the results of Experiment 5 makes one conclusion inescapable: the Session 14 burying durations are related to group membership. For Group LS, the experience of burying that had functional consequences led to increased burying in Session 14. For Group LSH, burying behavior that moved large amounts of sawdust, yet had minimal functional consequences, led to almost no change in the duration of burying across sessions. For Group SS, the inability to carry out the

burying response in any successful manner led to a decrement in CDB that might best be described as extinction.

Table 9

Experiment 5: Comparison of Observed Cell Means and Means Expected Under Zero Interaction

OBSERVED				EXPECTED			
	Sess 6	Sess 14			Sess 6	Sess 14	
LS	39.09	92.49	65.79	LS	59.31	72.27	65.79
LSH	34.73	41.29	38.01	LSH	31.53	44.49	38.01
SS	24.26	3.14	13.70	SS	7.22	20.18	13.70
	32.69	45.65	39.17		32.69	45.65	39.17

DIFFERENCE (OBSERVED-EXPECTED)
Sess 6 Sess 14

LS	-20.22	20.22
LSH	3.20	-3.20
SS	17.04	-17.04

The fifth hypothesis, that no statistically significant differences between groups would be obtained in this experiment is rejected. Conditioned defensive burying is under the control of its consequences.

Experiment 6

Regardless of whether organismic variables play a role in terminating CDB, a second possible controlling variable (and the two are not mutually exclusive) is visibility of the stimulus. In an attempt to determine whether termination of CDB is a function of stimulus visibility, two groups of rats, working under a lever-press-for-water contingency, were shocked through a back-lighted, Plexiglas lever. For both groups, the chamber substratum consisted of Plexiglas blocks. For one group (B), the blocks were opaque black, and for the other (C), they were transparent and clear.

Method

Subjects. Twenty-four Sprague-Dawley albino male rats served as subjects. Fourteen of the rats had served previously in an introductory experimental psychology class, and had the same histories as the rats in Experiments 1 through 4. They were 144 days old and weighed between 390 and 440 gr on the first day of training. The other 10 rats were experimentally naive, 94 days old, and weighed 350 to 400 gr on the first day of training.

The rats were randomly divided into two groups of 12, with the limitation the groups would be equivalent for the number of younger and older rats.

Apparatus. The same type of chamber employed in Experiment 3 was used for this experiment, with the following alterations:

1. The response lever was replaced with the translucent, plexiglas lever used in Experiment 5, and a high-intensity lamp was placed outside of the chamber, directly behind the back end of the

- lever. The lamp caused the lever to appear to glow, increasing its visibility.
2. A plywood floor was placed above the metal grid floor such that the distance from the floor to the bottom of the lever was 1 cm.
 3. The spout was raised so that its lowest edge was 1.3 cm above the new floor.
 4. A 0.6 cm hole was drilled through the left chamber wall, 1.0 cm above the floor and 1.8 cm from the front wall.

The chamber's substratum consisted of 240 Plexiglas blocks measuring 0.6 x 1.6 x 2.4 cm (the same length and width as the wooden blocks used by Pinel & Treit, 1979, but two-thirds as thick). All the blocks' edges and corners were sanded smooth. Two types of blocks were used, clear (uncolored), transparent, or black, opaque. Covering the lever with the black blocks blocked it from view, but covering it with clear blocks allowed it to shine through the substratum and to remain clearly visible.

Procedure. The same procedures used in Experiment 5 for training, testing, and measurement of burying durations were used in this experiment. The same procedures were used for water in the spout. Unlike previous experiments, however, an upper limit was not placed on the number of shocks that could be delivered. In Sessions 6 and 14, any animal that recontacted the lever within 15 minutes of the last shock, without first having engaged in at least 10 seconds of CDB, received another 10 mA shock.

For Group B, all sessions were run using the black, opaque blocks, and for Group C, the clear, transparent blocks were used. The lamp behind the lever was lit continuously throughout all sessions for both groups. Each session was begun with all the blocks pushed to the

back half of the chamber.

On some occasions, the rats pushed blocks directly under the lever. Whenever this occurred and it appeared that a rat was attempting to press the lever, the experimenter inserted a short piece of wire coat hanger through the hole in the left wall of the chamber and moved the blocks out of the way.

Following the completion of each rat's session, the chamber floor and the blocks were quickly wiped with a paper towel. At the end of each day's sessions, the blocks and the floor were washed with soap and water and left to dry overnight.

Results and Discussion

All rats learned to press the lever for their water needs. No burying of the lever occurred prior to the first shock delivery. As in the previous experiments employing the lever-press-for-water contingency, a single shock was not sufficient to elicit burying from any rat. Additionally, however, the second shock also failed to elicit burying from a majority of rats. The numbers of shock deliveries and numbers of animals that engaged in CDB in Session 6 are listed in Table 10.

A t-test comparing the groups' mean burying durations during Session 6 indicated that the difference was not statistically significant ($t=1.20$; $df=22$; $p=0.24$). The SMD demonstrated a medium effect size ($SD=72.79$; $SMD=0.49$). Thus, the difference in the groups' mean burying durations in Session 6, although being of medium effect size, was not significant, statistically. The groups' mean burying durations and numbers of lever presses in all sessions are presented graphically in Figure 6. The peak in lever presses in Session 4 was due to a malfunction of the water dispenser, which decreased its output.

Table 10

Experiment 6: Numbers of Shock Deliveries and Rats Engaging in CDB in Session 6

GROUP	C	B
1 Shock	0	0
2 Shocks	4	5
3 Shocks	8	6
4 Shocks	0	1
Mean(Shocks)	2.67	2.67
SD(Shocks)	0.49	0.65
Buried	9	11
Mean Duration (seconds)	96.80	61.43

During Session 7, very little burying occurred, but only four rats returned to pressing the lever. No burying occurred in Session 8, and by the tenth session, lever-press response rates approached pre-shock levels.

The rats' behavior in Session 14, the next shock session, was similar to that in Session 6, except that only one rat in Group B required a third shock. All of the rest engaged in CDB or avoided the lever after the first or second shocks. The same number of rats in each group engaged in CDB. The numbers of shock deliveries and number of animals in each group that engaged in CDB are listed in Table 11.

A t-test comparing the groups' mean burying durations during Session 14 indicated that the difference was not statistically significant ($t=-2.00$; $df=22$; $p=0.06$). The SMD demonstrated a reasonably large (Cohen, 1977) effect size ($SD=102.19$; $SMD=-0.77$). In summary, the differences in the groups' mean burying durations in Session 14, although being fairly large in effect size, were not significant, statistically.

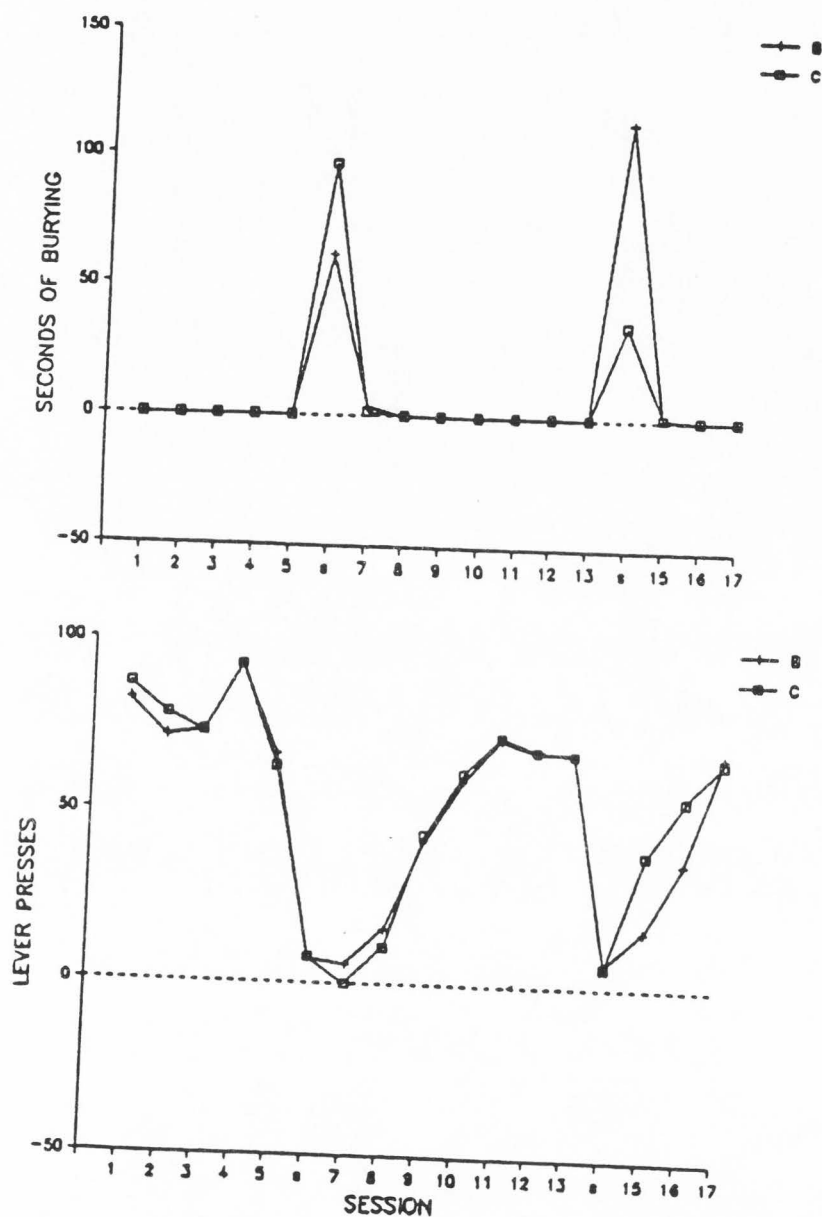


Figure 6. Experiment 6: Group mean burying durations and numbers of lever presses across sessions. Shocks were delivered in Sessions 6 and 14.

Table 11

Experiment 6: Numbers of Shock Deliveries and Rats
Engaging in CDB in Session 14

GROUP	C	B
1 Shock	2	0
2 Shocks	10	11
3 Shocks	0	1
Mean(Shocks)	1.83	2.08
SD(Shocks)	0.39	0.29
Buried	9	11
Mean Duration (seconds)	36.70	115.30

In order to compare the two groups' performances across both shock sessions, a two-way analysis of variance (Groups X Shock Session) was carried out (see Table 12). Only the interaction between groups and burying session was statistically significant. Eta^2 s of 0.02 and 0.11 indicated that 2% and 11% of the variances were associated with group membership and the group-by-session interaction, respectively.

To assist in the examination of the statistically significant interaction obtained in the two-way analysis of variance, the observed cell means and the cell means that would be expected under the assumption of zero interaction are shown in Table 13.

Table 12

Experiment 6: Two-way (Groups X Shock Session) Analysis of Variance

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio	Probability
Btwn Groups	1	5607.36	5607.36	0.78	0.53
Btwn Sessions	1	117.81	117.81	0.02	0.92
Interaction	1	38988.00	38988.00	5.40	0.02
Error	44	317442.50	7214.60		
Total	47	362155.70	7705.44		

Table 13

Experiment 6: Comparison of Observed Cell Means and Means Expected Under Zero Interaction

OBSERVED			EXPECTED				
	Sess 6	Sess 14		Sess 6	Sess 14		
C	96.81	36.68	66.75	C	68.31	65.18	66.75
B	61.43	115.29	88.36	B	89.92	86.79	88.36
	79.12	75.99	77.56		79.12	75.99	77.56

DIFFERENCE (OBSERVED-EXPECTED)
Sess 6 Sess 14

C	28.50	-28.50
B	-28.50	28.50

The mean burying durations of both Groups C and B differed from what would be expected under zero interaction (Table 13, lower panel). The statistically significant interaction resulted from the mean burying durations of both groups, which differed markedly from

those that would be expected.

SMDs were calculated for each group, comparing the mean burying durations in Session 6 with those of Session 14. The respective standard deviations, pooled for Sessions 6 and 14, and SMDs for each group are as follows: Group C, $SD=78.73$, $SMD=-0.76$; and Group B, $SD=96.45$, $SMD=0.56$. According to Cohen's (1977) criteria, these differences are fairly large for Group C and medium for Group B.

Overall, an examination of the results of Experiment 6 failed to answer many questions. No difference between groups was statistically significant. Furthermore, the only meaningful within-group difference was the comparison of burying durations of Sessions 6 and 14 for Group C. The statistically significant interaction, however, again showed that CDB is a function of its consequences.

The sixth hypothesis, that no statistically significant differences between the groups' burying durations would be obtained, is retained.

CHAPTER V

GENERAL DISCUSSION

Earlier in this paper, it was stated that, "although much is known about the conditions necessary for its elicitation, very little is known about the entire process" of conditioned defensive burying. Prior to the running of the experiments described in this paper, none had been run which examined the possibility that learning in rats occurred as a function of their engaging in CDB. The single-trial experiments run prior to these examined only variations in conditions related to the elicitation of CDB. Thus, it was not possible to determine whether conditioned defensive burying was in any way controlled by the consequences of the burying; that is, whether the rats' response durations are controlled by the effects of their burying on the environment.

In an attempt to make this determination, a series of six experiments was run, each with a specific objective and each testing a specific hypothesis. As a group, the studies were designed to answer one larger question: is conditioned defensive burying controlled by its effects on the environment? It is.

The first objective was to demonstrate that CDB could be obtained in our laboratory when the standard, one-trial methodology was employed. The associated hypothesis was that CDB would be obtained in this manner, and it was obtained.

The second objective was to test a method to force

the rats to recontact the lever, the source of the aversive stimulus, following the first shock delivery. This was necessary in order to be able to determine later what the rats learned while burying. The hypothesis associated with the second objective was that a lever-press-for-water contingency would result in the rats recontacting the lever even after they had received shocks through it. They did.

Of additional interest in Experiment 2 was the fact that, initially, a single shock was not sufficient to elicit CDB. A second punished lever contact was required. This result is similar to the results obtained in some taste aversion experiments (e.g., Cheney & Eldred, 1980; Garcia et al., 1977), in which aversions to a familiar CS are more difficult to establish than are aversions to novel stimuli. The need for more than one shock delivery remained constant throughout the other experiments.

The third objective was to carry out successfully a systematic replication of Experiment 2, with two different strains of rats, in order to confirm that the methodology employing the lever-press for-water contingency was sound, and that both strains rats could be forced to return to the lever consistently after engaging in CDB. The third hypothesis was that the results of the third experiment would be functionally equivalent to those obtained in Experiment 2. They were.

Another result of Experiment 3 was that each of the three albino rats engaged in longer durations of burying than each of the hooded rats. This result does not agree with the results of a similar, larger, group study run in another lab (McKim & Lett, 1979).

The finding in Experiments 2 and 3 that all of the subjects buried the lever completely, while in an extreme state of water deprivation, is of further interest in another context. Davis, Hazelrigg, Moore, and Petty-

Zirnstern (1981) had reported previously that CDB is attenuated by water deprivation. It appears, therefore, that the effects of this variable are not linear. Otherwise, smaller durations of burying, or none at all, would have been obtained.

The first three experiments employed shock as the aversive, eliciting stimulus, thus demonstrating that shock could elicit CDB reliably in our laboratory in both the standard and the lever-press-for-water procedures. One remaining question was whether, in the lever-press-for-water procedure, the burying was a function of the shock, rather than being the result of any change in the lever's function away from an exclusive association with reinforcement.

The fourth objective was to verify that the burying obtained in the second and third experiments was a function of the application of the aversive stimulus, shock, and that burying would not occur as a function of a less extreme alteration of the stimulus qualities of the response lever, such as extinction. The fourth hypothesis was that, under these conditions, CDB would not occur. It did not.

The functional results of conditioned defensive burying may be twofold. Burying a stimulus not only covers it, thereby potentially preventing the animal from further contact with it; burying also blocks the stimulus from view.

Objective 5 was to determine whether CDB is affected by varying the potential totality of its results, that is, to allow the CDB response, yet, at the same time, to vary the functional consequences of the response. The fifth hypothesis was that such a manipulation would not result in statistically significant differences in group mean burying durations. The manipulation did result in statistically significant differences, but only for the

group with an abundance of sawdust and no hole beneath the lever (i.e., the standard CDB configuration) as compared to the other two groups. The other two groups did not differ statistically.

There were only small differences in group mean burying durations for the first shock session. For the second shock session, however, the differences in group mean burying durations were quite large, and statistically significant differences between groups were obtained, as well as a statistically significant interaction between Groups and Shock Sessions. The burying behavior of Group LS, which had an abundance of sawdust, increased, as an apparent result of its functional success in covering or blocking the lever from view in the first shock session. The burying durations of Group LSH, which had the same amount of sawdust as Group LS, but which had the hole under the lever opened during burying, remained nearly constant. The burying of Group SS, which had a minimum amount of sawdust, so that covering or blocking the lever from view was impossible, appeared to have extinguished almost completely in the second shock session. In conclusion, prior CDB experience appears to play an important role in subsequent conditioned defensive burying.

The sixth objective was to determine whether CDB is affected by varying one function of its results, the rats' ability to see the source of the aversive stimulus. The sixth hypothesis was that no statistically significant differences between the groups' mean burying durations would be obtained. This objective was obtained, but, again, under specific circumstances.

Mean burying durations for the two groups during the first shock session showed medium differences in effect size, but the difference between the groups' means was not statistically significant. In the second shock session,

however, the mean burying duration of Group B, which could block the shock source from view, almost doubled, compared to the first shock session, and the mean burying duration of Group C, which could not block the shock source from view, decreased to about one-third of what it previously had been. Despite the size of this difference, it was not statistically significant.

The changes in the two groups' mean burying durations from Session 6 to Session 14 did result in a statistically significant Group X Session interaction, however, in which both groups' means deviated from what would be expected under zero interaction. An examination of each groups' effect sizes across the two shock sessions indicates that the interaction was due to both the decrease in burying by Group C and the concomitant increase by Group B. Thus, the sixth hypothesis, that no statistically significant differences between the groups' mean burying durations would be obtained, is retained.

It is important to note that the trends exhibited by the groups in Experiment 6 parallel those of the groups in Experiment 5, in that the group that could block the lever from view increased its mean burying duration across shock sessions, and the group that could not block the lever from view exhibited a decrease in burying duration. Essentially, Experiment 6 produced the same results as Experiment 5, with respect to the changes in burying durations across sessions.

In each of the five experiments in which CDB was elicited in this paper, the changes in behavior were large. In the fifth and sixth experiments, however, the changes were not in the direction suggested at the beginning of this paper, where the expectation was that if CDB durations were a function of stimulus visibility, termination of the response would occur shortly after the source of the aversive stimulus was blocked from view. In

fact, just the opposite occurred.

Typifying the results of reinforcement and extinction procedures, groups of animals that are able to cover and/or block from view the shock source increase burying durations over shock trials, and those that are unable to do so decrease burying durations over shock trials. This is strong evidence that conditioned defensive burying is a function of its consequences; as a response, burying is related to the functional changes it produces in the environment.

Earlier work prevented this evidence from surfacing because the single trial experiments were designed to study elicitation, and did not provide the subjects an opportunity to demonstrate the differential learning that occurs. Future work in this area could be carried out in a number of areas. First, there is a need for further investigation regarding stimulus visibility as the critical variable in controlling CDB elicited by tactile aversive stimuli. This could begin with a replication of the sixth experiment in this paper.

Second, work could be done investigating the degree to which CDB alters the effects of punishment. Shocking the rats through the lever during the lever-press-for-water contingency parallels closely the use of grid shock in traditional punishment experiments (cf. Azrin & Holz, 1966). In both situations, lever-pressing is suppressed following shock delivery. Would there be a difference in recovery of lever-pressing baselines between groups that can bury compared to groups with no substratum at all?

Third, is conditioned defensive burying sensitive to externally imposed contingencies? Experiments could be run using the lever-press-for-water contingency in which other stimuli are manipulated during the occurrence of CDB. For example, stimuli such as loud noise or bright light could be used as punishers and negative reinforcers

contingent on the burying response.

There is still much to discover about conditioned defensive burying. What is clear already is that it does not fit two-process learning theory. Under two-process theory, CDB would have to be either a respondent, and not be controlled by its consequences, or an operant, and not be elicited by a novel, unconditioned aversive stimulus. However, conditioned defensive burying, like other SSDRs, is both elicited and controlled by its consequences. It is a directed behavior that occurs following a single stimulus exposure, but it is controlled by its consequences as well. This implies that its analysis does not require the use of two-process learning theory.

Rescorla (1988) points out that respondent "conditioning is not the shifting of a response from one stimulus to another. Instead, conditioning involves the learning of relations among events that are complexly represented, a learning that can be exhibited in various ways" (p. 158). It is not necessary to posit more than one type of learning in order to explain more than one type of behavior.

It is apparent from the descriptions in this paper that the rats learned many relations during the experiments. The rats learned about relations between the lever and water, the lever and painful stimulation, and their own manipulation of the environment and the lever. The learning of each of these relations was exhibited clearly in the rats' changing performances of both lever-pressing and conditioned defensive burying. The burying performances exhibited by the subjects in these experiments demonstrate that like other species-specific defense reactions, conditioned defensive burying is controlled by its consequences.

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- Williams, D. R., & Williams, H. (1969). Auto-maintenance in the pigeon: Sustained pecking despite contingent nonreinforcement. Journal of the Experimental Analysis of Behavior, 12, 511-520.
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VITA

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SUMMARY**CLINICAL/
APPLIED
EXPERIENCE**

Associate Director, Behavioral Medicine Program; Behavior Therapy/Modification with chronic pain and illness patients, oncology-bone marrow transplant patients, psychiatric inpatients, hospitalized developmentally disabled adults, sheltered workshop clients, behaviorally disordered adolescents, and severely/profoundly handicapped elementary students; Staff Training in all settings.

**TEACHING
EXPERIENCE**

University courses in General Psychology, Analysis of Behavior-Basic Principles, Introduction to Behavior Modification. Workshops in Behavioral Assessment, Writing and Implementing Treatment Programs. Invited Lectures on the Behavioral Treatment of Chronic Pain, Psychophysiology of Pain, and Study Methods for College Students.

RESEARCH EXPERIENCE Behavioral Medicine, Behavior Therapy, Behavior Modification, Operant Conditioning with Humans, Animal Model of Chronic Pain, Defensive/Avoidance Behavior in Rats.

PROFESSIONAL INTERESTS Pain Control, Behavioral Medicine, Behavior Therapy, College Teaching; Administration in all areas; Research, Practicum, and Internship Supervision; Psychological and Computer Applications in Business.

EDUCATION

DOCTOR OF PHILOSOPHY Psychology, 1988, Utah State University, Logan, Utah.

MASTER OF ARTS Behavior Modification, 1977, Rehabilitation Institute, Southern Illinois University, Carbondale, Illinois.

BACHELOR OF ARTS Psychology, 1975, San Francisco State University, San Francisco, California.

PROFESSIONAL TRAINING

TEAM TREATMENT IN COUPLE COUNSELING Introduction (35 hours) and Advanced (20 hours), 1973, 1974. The techniques of sex therapy as developed by Masters and Johnson. Taught through the Calif. Dept. of Health by Thomas Lowry, M.D., & Thea Lowry, M.A., formerly of the Masters & Johnson Reproductive Biology Research Foundation, St. Louis, MO.

PROFESSIONAL EXPERIENCE

CLINICAL/ Senior Research Fellow in Psychology, 1987-
APPLIED Present. Pain & Toxicity Research Program,
Fred Hutchinson Cancer Research Center, Seat-
tle, WA, C. Richard Chapman, Ph.D., Karen L.
Syrjala, Ph.D. Implement pain reduction re-
search; design and implement similar related
research; serve as part of a consultation team
in treating pain, anxiety, stress, and family
loss in a bone marrow transplantation setting.

Director of Psychological Services, 1983-1987.
Hillside School, Inc., Logan, UT, Phyllis R.
Publicover, Ph.D. Development and implementa-
tion of treatment plans for severely emotion-
ally disturbed adolescents in residential
treatment; hire, train, and supervise thera-
pists and milieu staff; individual and group
therapy. Developed policies, procedures, and a
clinical record maintenance system for JCAH
accreditation. Behavioral Consultant, 1983.
As per above on an as-needed basis.

Associate Director and Co-Founder, Behavioral
Medicine Program/Pain Clinic, 1982-1983.
Logan Regional Hospital, Logan, UT, Calvin R.
Petersen, Ph.D. Designed, established,
marketed, and coordinated a multidisciplinary
treatment unit for patients suffering from
chronic pain and illness. Provided direct
patient care, patient management, and
interdepartmental coordination; individual,
marital, and family therapy; staff training.

Psychology Intern, 1978-1979 (American Psychological Association Approved Internship).

- A. Veterans Administration Medical Center, Salt Lake City, UT, Sid Gelfand, Ph.D. Development and implementation of treatment programs for psychiatric inpatients; consultant for behavior therapy and modification programs; co-developed ward token economy program. Carried out assessment, intake, and triage in the Psychiatric Pre-Admission Assessment Unit (5/8 time).
- B. Division of Behavioral Medicine, Dept. of Psychiatry, University of Utah Medical Center, Salt Lake City, Steven Zlutnick, Ph.D. Development and implementation of treatment programs for chronic pain and illness patients and their families; trained University of Utah graduate students in treatment procedures (3/8 time).

Assessment Specialist, 1977-1978. Exemplary Service Project, Exceptional Child Center, Utah State University, Sebastian Streifel, Ph.D. Developed and conducted replicable procedures for assessments, diagnoses, and eligibility determination in a model demonstration program serving severely/profoundly retarded, multiply handicapped elementary students; inservice training to staff.

Work Adjustment Training Coordinator, 1976-1977. Jackson Community Workshop/Activity Center, Murphysboro, IL, Dean Brandenburg. Development and implementation of work adjustment and developmental training plans for shel-

tered workshop and work activity clients; inservice training to staff; supervised graduate and undergraduate practicum students from Southern Illinois University, Carbondale.

Intern, 1976. Southern Illinois University Clinical Center, Roger Poppen, Ph.D. Behavior therapy with individual students and couples.

Behavior Modification Paraprofessional, 1976. Carbondale (IL) Special Education Co-op, Marvin Ott. Development and implementation of training programs for severely/profoundly retarded, multiply handicapped elementary students; inservice training for teaching staff.

Practicum Student, 1975. Franklin-Williamson County Workshop, Rehabilitation Institute, Southern Illinois University, Richard Sanders, Ph.D. Developed a training procedure to teach eye contact skills in social interactions to the visually impaired.

Student Assistant, 1974-1975. Napa State Hospital, Imola, CA, David Loberg, Ph.D. Full-time provision of direct-care services to developmentally handicapped adults; self-help training employing behavior modification procedures.

Family Counseling Trainee, 1973-1974. Pacifica (CA) Youth Service Bureau, Mark Savage. Part-time volunteer in child and family therapy for clients referred by schools and police for behavioral problems. Supervisor, Drop-in Center,

1973. Paid supervisor of the Bureau's Drop-in Center for adolescents as part of an ongoing delinquency prevention program.

Houseparent, 1971-1972. Sacramento (CA) Residential Treatment Center, Carl Fransham & Jay Sindorf. General parenting for seven behaviorally disordered adolescents; development of working relationships with collaterals, such as school personnel and police.

Head Resident, 1969-1971. The St. George Homes, Inc., Berkeley, CA, Dorothea Romankiw. Primary responsibility for maintaining the overall milieu for behaviorally disordered adolescents; staff supervision and training; teaching and training of residents.

TEACHING

Instructor, Summers, 1982-1983, 1985-1986. Dept. of Psychology, Utah State University, Blaine Worthen, Ph.D., Dept. Head. General Psychology, an introductory survey course.

Instructor, Fall, 1985. Lifespan Learning, Utah State University, Kevin Kirk, M.A. General Psychology, evening class on USU campus.

Instructor, Spring, 1985. Extension Division, Utah State University, Weldon Sleight, Ph.D. General Psychology and Analysis of Behavior-Basic Principles, in Tooele, UT.

Instructor, 1980-1981. Dept. of Psychology, Utah State University, Carl Cheney, Ph.D.

Analysis of Behavior-Basic Principles, a course in basic and applied behavior analysis, including animal laboratory experience.

Teaching Assistant, 1979-1980. Dept. of Psychology, Utah State University, Richard Powers, Ph.D. General Psychology.

Teaching Assistant, Summer, 1976. Rehabilitation Institute, Southern Illinois University-Carbondale, Richard Sanders, Ph.D. Co-taught Introduction to Behavior Modification to inmates inside the U.S. Federal Penitentiary at Marion, IL, the maximum security facility built to replace the obsolete prison located on Alcatraz Island.

PSYCHOLOGY Animal Laboratory Assistant Manager, 1981-1982.

RELATED Dept. of Psychology, Utah State University, Carl Cheney, Ph.D. Maintained environment and cared for laboratory animals. Taught others to implement their research on various experimental apparatus.

Director, Day Camp, Summer, 1974. Marin County (CA) Jewish Community Center, Murray Narell. Interviewed, hired, trained, and supervised 30 staff for a program serving 175 children, aged 5-13; development and coordination of overall program. Unit Head, Day Camp, Summer, 1973. Assistant Director as per above.

COMPUTERS President and Founder, Practical Support Associates, 1985-Present (Part-time business in home). Consultation and custom programming applications for local businesses; national marketing of personally developed gradekeeping software for educators (Teacher's Pet Version 1.10, Copyright 1986, Stephen G. Goldberg).

PROFESSIONAL AFFILIATIONS

STUDENT MEMBER American Psychological Association.
OR EQUIVALENT Division 25: Analysis of Behavior.
 Division 38: Health Psychology.

Association for Behavior Analysis.

Association for the Advancement of
 Behavior Therapy.

Behavioral Medicine Special Interest
 Group.

International Association for the Study of
 Pain.

Society for Behavioral Medicine.

PSYCHOLOGY PUBLICATIONS

Goldberg, S. G., & Sanders, R. M. (1977). Eye contacts:
 Increasing their rate in social interactions. Journal
of Visual Impairment and Blindness, 71, 265-267.

Goldberg, S. G., Ghezzi, P. M., & Cheney, C. D. (1983). Rat defensive behavior: Burying an operandum associated with reinforcement. The Psychological Record, 33, 191-199.

Goldberg, S. G., & Cheney, C. D. (1984). Effects of chronic shock on cooperation: A potential model of learned chronic pain behavior. Psychological Reports, 55, 899-906.

Goldberg, S. G. (1988). Psychology and cancer pain: Theory, practice, and a critical review of research-oriented interventions. Manuscript submitted for publication.

PSYCHOLOGY PRESENTATIONS

Goldberg, S. G., & Sanders, R. M. (1977, May). Increasing the rate of eye contacts in a blind client's social interactions. Paper presented at the meeting of the Midwestern Association of Behavior Analysis, Chicago, IL.

Goldberg, S. G. (1977, November). The role of assessment in teaching. In Teaching techniques used with the severely/profoundly handicapped. Mini-workshop presented at the meeting of the Utah Chapter, American Association on Mental Deficiency, Logan, UT.

Goldberg, S. G. (1978, May). Extinction as a function of the interpolation of continuous and partial reinforcement in human operant responding. Paper presented at the meeting of the Midwestern Association of Behavior Analysis, Chicago, IL.

- Goldberg, S. G., & Cheney, C. D. (1981, November). Rat defensive behavior: Burying a noxious water source. Paper presented at the meeting of the Utah Academy of Sciences, Arts and Letters, St. George, UT.
- Goldberg, S. G., Ghezzi, P. M., & Cheney, C. D. (1981, November). Rat defensive behavior: Nonelicitation by a stimulus associated with extinction. Paper presented at the meeting of the Utah Academy of Sciences, Arts and Letters, St. George, UT.
- Goldberg, S. G., & Cheney, C. D. (1982, April). Rat defensive behavior: Interstrain differences in burying a noxious water source. Paper presented at the meeting of the Utah Academy of Sciences, Arts and Letters, Ogden, UT.
- Goldberg, S. G., & Cheney, C. D. (1982, April). Rat defensive behavior: Procedural Variations and the burying response. Paper presented at the meeting of the Utah Academy of Sciences, Arts and Letters, Ogden, UT.
- Goldberg, S. G., & Petersen, C. R. (1983, April). Establishing a behaviorally oriented multidisciplinary pain clinic in a rural community hospital. Paper presented at the meeting of the Rocky Mountain Psychological Association, Snowbird, UT.
- Goldberg, S. G., & Cheney, C. D. (1983, June). Chronic pain: An animal model of responding in humans. Paper presented at the combined meeting of the Pacific Division and the Southwest and Rocky Mountain Division of the American Association for the Advancement of Science, Logan, UT.

COMPUTER PUBLICATIONS

Goldberg, S. G. (1986, June). Splitting procedures into programs. Data Based Advisor, pp. 42, 44, 50.

Goldberg, S. G. (1987, February 24). Clearing with Clipper. In "Power User." PC Magazine, p. 301.